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ABSTRACT

This report presents four papers about the use of technologies in education and a policy statement of the Council of Chief State School Officers (CCSSO). The papers were commissioned for a conference designed to stimulate discussion and action among leading technology specialists at all levels of education, private sector representatives, and technology experts from state education agencies. Each of the papers addressed one of the four key issues considered at the conference, i.e., learning alternatives created with technology, student outcomes of learning technologies, integration of technology into teaching, and planning for learning technologies. The papers are: (1) "Learning Alternatives: Technology in Support of Lifelong Education" (David D. Thornburg); (2) "To Lead or To Follow: The Role and Influence of Research on Technology" (Saul Rockman); (3) "Technology Integration and Teachers' Professional Development" (Karen Sheingold); and (4) "Planning for the Technology-Rich Learning Environments of the Future" (Barbara O'Connor). It is noted that the policy statement which concludes the report--"Improving Student Performance through Learning Technologies"--is based in large measure on deliberations about these papers by the 175 participants in the conference, and that it outlines the action required at several levels of government to achieve full integration of technology into education. (ALF)

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# LEARNING TECHNOLOGIES ESSENTIAL EDUCATION CHANGE

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# Council of Chief State School Officers

The Council of Chief State School Officers (CCSSO) is a nationwide non-profit organization of the 57 public officials who head the departments of elementary and secondary education in every state, the District of Columbia, the Department of Defense Dependents Schools, and the five extra-state jurisdictions. CCSSO seeks its members' consensus on major education issues and expresses their views to civic and professional organizations, federal agencies, Congress, and the public. Through its structure of committees and task forces, the Council responds to a broad range of concerns about education and provides leadership on major educational issues.

Because the Council represents chief education administrators, it has access to the educational and governmental establishment in each state and the national influence that accompanies this unique position. CCSSO forms coalitions with many other education organizations and provides leadership on a variety of policy concerns that affect elementary and secondary education. Thus, CCSSO members are able to act cooperatively on matters vital to the education of America's young people.

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**Policy Statement: Improving Student Performance Through Learning Technologies**

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The 175 participants in CCSSO's Fifth State Technology Leadership Conference—from all levels of education and the private sector—provided extraordinary assistance in reviewing and revising the policy statement.

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# INTRODUCTION

This book—**Learning Technologies: Essential for Education Change**—includes four thoughtful papers about the use of technologies in education and an important policy statement of the Council of Chief State School Officers (CCSSO). The book is part of the Council's effort to support initiatives to improve teaching and learning through the use of learning technologies. The papers were commissioned for CCSSO's Fifth State Technology Leadership Conference held in Dallas, Texas from October 31 through November 3, 1991. The Conference was designed to stimulate discussion and action among leading technology specialists at all levels of education, private sector representatives, and technology experts from state education agencies. The Council invited four expert researchers to give presentations on four key issues: learning alternatives created with technology, student outcomes of learning technologies, integration of technology into teaching, and planning for learning technologies.

The policy statement at the end of this book is based in large measure on deliberations about these papers. The 175 participants in CCSSO's Fifth State Technology Leadership Conference developed a draft policy statement on learning technologies, which was unanimously adopted by the chief state school officers in November 1991. The policy statement, **Improving Student Performance Through Learning Technologies**, provides a vision of the power of learning technologies and outlines the action required at the several levels of government to achieve full integration of technology into education.

Learning technologies are essential for successful education change. They have enormous potential to stimulate and enhance education reform and to prepare students to be productive workers and responsible citizens in the 21st century. Many states, districts, schools, and classrooms have used technology to create innovative, stimulating, effective learning environments. However, the gap between the current potential and actual use of technology is tremendous. The challenge is to stimulate systemic education change—to move beyond model programs to widespread use of technology to alter and improve education.

The Council of Chief State School Officers accepts this challenge and invites key decision makers in both the public and private sectors to review these informative papers and join in the implementation of the policy recommendations.

# Learning Alternatives: Technology in Support of Lifelong Education

David D. Thornburg, Ph.D.
Director, Thornburg Center for
Professional Development

## EXECUTIVE SUMMARY

*In times of change, learners inherit the earth, while the learned find themselves beautifully equipped to deal with a world that no longer exists.*
Eric Hoffer

Unless modern technology is incorporated extensively in public education, our schools will cease to be relevant to our students' lives. We live in a world of increasingly rapid social and technological change. As education is being restructured to create a nation of lifelong learners who are able to thrive in this new world, pedagogy is shifting from "teaching as telling" to a more child-centered constructivist approach.

Rapid developments in technology are allowing the creation of ever-more powerful tools while prices for these tools stabilize or decline. Furthermore, these technologies make it easier to incorporate effective pedagogies because they facilitate the process by which students become constructors of their own knowledge. The textbook is obsolete in the new paradigm; technologies like CD-ROM's and laser videodiscs in the hands of students help implement a curriculum that ensures their lifelong engagement with learning.

Most new information technologies of value to education appear in the consumer marketplace first. The success of products in the home ensures their availability to educators. Unfortunately, this "consumer market first" approach makes it more likely that educators will remain unaware of these tools until long after they have been used by students.

Some students now have access to pocket electronic encyclopedias. As this technology becomes ubiquitous we will have to restructure teaching and, yet, most schools have yet to restructure the basic math curriculum in a way that acknowledges universal access to pocket calculators. Technological change is exponential while educational change seems to be linear. This means that the gap between homes and classrooms as informational resources is widening at a rapid pace. Unless education adopts and adapts to new technologies, our schools will soon lose their relevance as primary places of learning.

While cost is still a factor impeding technology use in the classroom, the relatively small use of free technologies (e.g., instructional television) implies that inadequate staff development may be a large factor in the underuse of technology. Effective staff development must address both the spectrum of available technologies and their uses in a curriculum that honors the notion that every student is capable of learning. Staff development needs to be ongoing and educators must be provided sufficient release time to become comfortable with the tools of the information age.

# INTRODUCTION

## Education for the 21st Century

*To those who want to see real improvement in American education, I say: There will be no renaissance without revolution.*
President George Bush

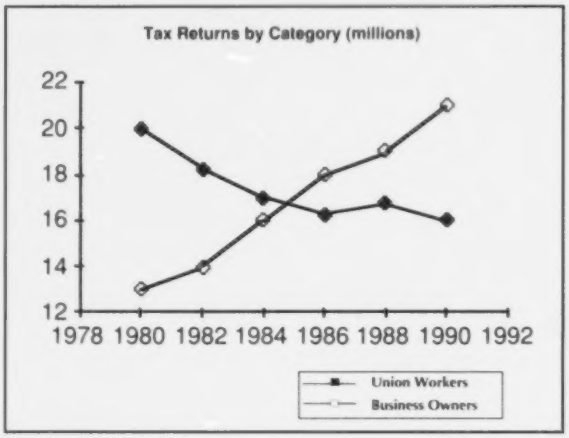
Until recently we have based our educational system on the assumption that a certain number of failures is tolerable even desirable because they provide a workforce ready for low-paying jobs.[1] Our country's needs have changed, however, and with these changes comes the realization that we must restructure education so that it reaches all students and helps them succeed. Some of our restructuring needs were expressed in President Bush's *America 2000* document[2] and were elaborated upon in the Business Roundtable's report on education.[3]

Because the underlying premise of the old model for educational institutions runs counter to the needs of students in the 21st century, we cannot achieve our goals by simply extending the school year, or by creating new tests of achievement. We need to redefine the meaning of education in terms of the post-industrial age. Technology has the power to help facilitate this change, but technology must be thought about in the context of meaningful restructuring of the educational process.[4] Thus, while the bulk of this report is devoted to educational technologies, the context in which these technologies is presented is explored as well. The reason for this is that technology can be applied in education to meet many objectives. Technology is, by itself, neutral. (The hammer with which Michelangelo created the Pieta can be used to destroy it.) For this reason, it is essential that we place pedagogy above technology and allow our focus on technological futures to be guided by core beliefs and understandings about our goals and our awareness of ways to develop and maintain a lifelong interest in education in all learners.

## Societal Change and Education

The world is changing, and the rate of change is accelerating. Numerous authors [5-8] have written about this topic over the years. But we no longer need to rely on the crystal balls of others to see changes in society. We can see changes for ourselves in employment patterns, the demographics of our communities, and the information technology found in our homes.

For example, consider the following graph of tax return information from the IRS:




This graph shows the decline in the number of blue collar workers and the concomitant rise in owners of small businesses over the past 10 years. Add to this the fact that the skills needed by blue collar workers have changed in the past decade and it is clear that our educational system needs to meet the needs of a very different clientele than it did just a decade ago.

Census data have shown remarkable changes in our population in the past decade - especially in the Pacific Rim states. For example, the following chart contains information about the changing population in our most populous state, California. The chart shows growth in Hispanic and Asian populations in the past decade, which translates into an increase in limited-English-speaking peoples. The changes reported in this chart are being felt elsewhere as well.

Technology and non-print literacy are commonplace in the life of our youth. The left-right, top-bottom world of Gutenberg has been joined by an explosion of non-linear and (in many cases) highly interactive information tools in the home. The following data from the Electronics Industries Association[9] show just how pervasive technology has become in our homes:

| Technology | January 1991 Penetration (% of U.S. Households) |
|---|---|
| Telephone | 99 |
| Color Television | 97 |
| Component Audio | 94 |
| VCR | 74 |
| Cable | 59 |
| Computer | 29 |
| Audio CD Player | 28 |
| Projection Video | 7 |

In looking at the data in this table, it is important to remember that the income of nearly 14 percent of U.S. households falls below the federal poverty levels.

### Educational Technology—The Acceleration of Change

We must always be on the lookout for new technologies that can have a positive effect on education; but this presents us with an immediate challenge: How do we plan for the future when technology is advancing by leaps and bounds? Our answer to this question is that we must first identify the solid curricular and pedagogical ideas that we believe in, and then equip our classrooms with the best technologies currently available to help us act on these ideas, with the understanding that some of these technologies may be augmented or replaced in the future.

This much is clear: We need to stop investing in technologies of the past—we are beyond the age of 16mm movie projectors. When you travel at the speed of light, you don't need a rear view mirror.

## WHAT ALTERNATIVES TO TRADITIONAL LEARNING ENVIRONMENTS DOES TECHNOLOGY OFFER?

*Children enter school as question marks and leave as periods.*
Neil Postman

Because lifelong learning is a central goal of education, we must be on the lookout for tools that engage all students in the joys of learning. In so doing, however, we must be careful not to merely look at technologies that entertain students. Unfortunately, the distinction between entertainment and engagement is unclear to some social commentators, and to some software developers as well. For example, Neil Postman, in his book *Amusing Ourselves to Death*,[10] decries the use of instructional television (ITV) and computers in the classroom as trivializing education. His criticism of such exemplary projects as the *Voyage of the Mimi*[11] demonstrates a lack of awareness of the benefits of using multimedia tools in education. Unfortunately, he is not alone in his criticism. *Time Magazine*'s article, *The Revolution that Fizzled*[12], criticized a major pilot project in technology-intensive education because the benefits were not immediately obvious to a local school board.[13]

Software developers, in some cases, have created very entertaining software packages devoid of meaningful educational content. The purchaser of educa-

tional technology must be a careful consumer whose educational objectives are clearly stated, and whose criteria for software selection are grounded in these objectives.

In fact, current educational technologies fit extremely well with educational models based on effective learning research by Gardner, Csikszentmihalyi, and numerous others.[14-18] The correlation between research on learning styles and engagement with the multi-sensory modalities supported by classroom computers, laser videodiscs, ITV, CD-ROM's, and so on is quite strong. The implementation of educational strategies based on pedagogical research has merit in itself. Connect these pedagogical ideas with technology, and that power is magnified.[19]

## TECHNOLOGIES

*A lot of things have happened in the 20th century, and most of them plug into walls.*
Fr. John Calkin

The challenge of presenting a comprehensive overview of educational technology in limited space is immense. First, developments are rapid on many fronts, virtually guaranteeing that new technologies will come into existence by the time this report is distributed. Second, there are so many technologies of potential value to education that an in-depth report on their significance would consume several volumes. Therefore, this paper explores only those technologies that, in my opinion, have the greatest potential to improve education in the near-future, that is, the next 2 to 4 years.

### Which Technologies Does Education Need To Access To Create Learning Activities?

#### Video display technologies

Most educational technologies produce sounds and video images. Though video projectors continue to be expensive, they are becoming increasingly important as educators increase their use of video and computers in the classroom. Ultimately, the video projection system will replace the blackboard as wall-sized, full-color images replace the hand markings of white chalk on a green board. This is already happening in industrial training facilities such as those of AT&T in Parsipanny, New Jersey, where one entire training room wall serves as a rear-projection screen for a variety of audio-visual equipment. While the cost and facilities demands of such systems are beyond the range of most public schools, less expensive projection video systems are being placed into classrooms, and a downward trend in prices will continue. For example, I would not be surprised to see a compact color video projection system priced at $500 enter the marketplace during 1992.

In the meantime, liquid crystal display plates that sit on traditional overhead projectors provide an adequate solution to the group display problem for computer images, and the new self-contained color video projectors provide excellent images for ITV and laser videodisc presentations. These devices range from $600 for a low-end display plate to about $6000 for a high-quality video projector. Note, however, that many color video projectors will only handle NTSC (television) signals. They can not display computer images from high-resolution computer systems such as the Apple Macintosh or IBM-compatible computers using EGA or VGA display systems. It is expected, however, that full-color "multi-sync" projectors that handle these computer signals will become more reasonably priced (under $3000) in the near future. In the meantime, "scan converters" are available that convert high-resolution computer images into the standard NTSC television format for use with existing video projectors. While some loss of resolution is inevitable, the resulting image quality is usually acceptable for presentation of information to a group.

Many classrooms currently display information on large television monitors. As technology becomes more integrated into the teacher's day, these relatively small screen devices will probably prove inadequate for group viewing on an extended basis, so they should be thought of as short-term solutions to the problem.

#### Instructional Television (ITV)

Even though it has been available at no direct cost for many years, instructional television has not been used very effectively in our schools. The reasons for this include:

- the perception that ITV is "boring,"
- a lack of awareness of what is available, and
- an unclear connection between ITV and curriculum.

Exemplary staff development projects, such as Texaco's venture with PBS affiliate Thirteen/WNET (New York),[20] have provided opportunities for teachers to develop curricular connections to ITV, to develop lessons around these offerings, and to share this knowledge with their peers. This successful program is being extended to ten sites nationwide, and should serve as a model for similar programs throughout the country.

Information providers such as Children's Television Workshop (CTW), The Discovery Channel, and

CNN, have realized the need for high-quality ITV suitable for classroom use and have developed many excellent programs. For example, CTW has created classroom versions of their popular 3-2-1 Contact series (Classroom Contact) in the form of 15-minute segments that can be integrated into existing classroom lessons.[21] These materials are being broadcast during "block feed" times in the middle of the night so they can be recorded and used in the classroom at the teacher's convenience. The Discovery Channel provides a one-hour broadcast each weekday morning (*Assignment Discovery*) consisting of documentaries for classroom use. Even though The Discovery Channel is a commercial operation, *Assignment Discovery* is commercial free, teachers are free to tape and show the program, and the material is curriculum-driven.[22]

ITV can provide information in ways that significantly outperform lectures. By using ITV to enhance presentation, the video tools can allow teachers to facilitate discussions and the development of higher-order thinking skills through critical viewing and analysis. ITV can be integrated with hands-on activities, and can be adapted to meet individual teaching and learning styles. It is possible that as teachers become more comfortable ITV and it becomes more widely used, it will move from being a supplement to a traditional lesson and take on a more significant role.

### Computers

Laptops are the fastest growing segment of the computer market and, like desktop machines, they are available in a wide range of prices and various capabilities. Apple, for example, has been one of the last major computer companies to enter this market, but they have just recently entered the marketplace with three laptop Macintosh computers.[23]

While desktop computers are still under-represented in most classrooms, we are fast-approaching the time when powerful laptop computers will be affordable for many students. For example, inexpensive notebook computers with word processors and database programs are now available for under $200 from vendors such as Laser.[24]

And desktop computers are continuing to drop in cost while increasing in capability. High-resolution color images that were the realm of high-end workstations a few years ago are now showing up on inexpensive (under $1000) computer systems. Improvements in graphics and user interface design have allowed the creation of educational software for personal computers undreamed of a decade ago.

For example, consider the program, *Math Connections: Algebra I*, from Wings.[26] This program allows a user to enter a mathematical function in a box that can then be connected to another box in which the graph of this function is shown. Anytime the user changes parameters in the function, the graph is redrawn, and anytime the user moves or reshapes a curve in the graphics screen, the parameters in the function window change to reflect the new curve. This brief description only hints at the power of this program as a tool for helping students understand mathematical functions through a variety of learning styles.

This application of technology is a far cry from the early days of educational computing when the focus was on teaching so-called "computer literacy" skills that included some understanding of hardware functions and some exposure to programming—usually in BASIC. Early educational software was primarily oriented toward drill and practice, although some efforts were made to incorporate information about Logo and some word processing.

Today's classroom computers are being used by students to create highly interactive multimedia reports using various "hypermedia" tools. Rather than restricting the user to linear sequential paths through information, hypermedia tools facilitate a more natural non-linear exploration. The power of this non-linear method of exploring knowledge was forecast in 1945 by President Roosevelt's science advisor, Vannevar Bush.[27] His prescient comments on this topic are included in Appendix A.

Two aspects of hypermedia make it particularly useful as a learning technology. These aspects are the flexibility it allows students in accessing information and the ease with which students and teachers can use it to create their own materials.

When computers first appeared in the classroom, one of the rationales for their use was that they allowed students to work at their own pace. Now, with hypermedia tools, students can work in their own style as well. For example, GTV (Geographic Television)[28] consists of a set of laser videodiscs and computer software designed to facilitate the exploration of American history. This project, funded in part by the State of California and produced by National Geographic and LucasArts, supports several methods of exploration by both teachers and students. At one extreme, material can be presented in sequence, and, at the other, users can browse through the content at will, leaving a trail to mark the path through this vast amount of data. The path can then be saved to disk for later playback, for inclusion in a report, or as a portion of a performance assessment of student knowledge.

Students and teachers can also use hypermedia to create their own materials from scratch. Images from traditional video sources can be stored as full-color pictures and incorporated into student reports.[29] Authoring environments such as HyperCard (Apple), and LinkWay (IBM), facilitate the creation of reports with richness that exceeds the power of the printed page. New developments in image compression now allow full-color videos to be captured in the computer memory for incorporation into hypermedia reports. And technology such as Apple's QuickTime[30] are making full-speed color animation commonplace in computer programs. These capabilities will be available on computer platforms from numerous vendors.[29]

One of the greatest powers of hypermedia authoring systems is that they facilitate the model of learners as constructors of their own knowledge. To be truly effective, however, computer access must be extended to all students—a goal that we have failed to address adequately.

Technology continues to be scarce in the classroom even though the positive effect of technology access on student performance has been documented[25], especially in the area of writing.

If we accept the Electronics Industries Association figures showing that 29 percent of all homes have personal computers, we know that children are more likely to encounter these tools outside of the classroom than within it. Because familiarity with computer use is fast becoming a survival skill in the business world, we must redouble our efforts to ensure equitable access to this technology for all children. The fact is that we, as a nation, can afford to insure access to powerful computer technology to all students - we have simply chosen to spend our resources elsewhere. The issue is not affordability, it is vision.

## Optical media

There is little question that one of the more exciting areas of educational technology development is optical media—laser videodiscs, CD-ROM's and so on. Each of the various media and formats is undergoing its own development cycle.

### a. Laser videodisc

Laser videodiscs have been commercially available for many years, yet they are just now becoming commonplace in education. The simplest application for this medium is as a distribution tool for instructional video. Unlike videotape, laser videodiscs do not wear out due to repeated use. They have much higher video quality than most tapes and with still-frame access, allow teachers to leave a single image on the screen for hours without any decrease in quality or damage to the medium.

Another distinguishing feature of videodiscs is their capacity for random access. Users can jump from frame to frame within a single side of a disc almost instantly—a feature that is impossible to achieve with tape.

Most educational videodiscs contain a combination of motion sequences and still frames. Motion sequences can incorporate two or more sound tracks, allowing, for example, bilingual recordings. For discs that allow still-frame access, 54,000 images can be stored on each side of the disc—accounting for 30 minutes of continuous video. So-called "extended play" discs sacrifice still frames for increased recording time of up to one hour per side.

The growth of educational titles on videodisc has been enormous in the past year. Previously developed ITV programs such as the *Voyage of the Mimi* have been released in this format, as have many new discs containing video segments that are unavailable in other formats. Visual libraries of information ranging from life sciences (such as the *BioSci II* disk from VideoDiscovery[31] and *Treasures From the Deep* from The Discovery Channel[32]) to space science (such as the *Space Disc* series from Optical Data Corporation[32]) are available on disc, providing educators with a vast library of raw images and video clips that can be incorporated into existing lessons. When used in this way, the videodisc player acts like a slide projector and videotape player but provides far easier access to information.

The most common method for accessing information on the disc is through the hand-held remote control that comes with most videodisc players. Users simply key in the frames or segments they want to see, and press a button to bring the information into view.

The release of Pioneer's laser bar code reader[33] (licensed to other vendors as well) has simplified videodisc access even more. With this inexpensive device the user simply runs the pen over a printed bar code and presses a single button to transmit the data to the player. Virtually no training is required to use this tool effectively. Users can create their own bar codes on their computers or use textbooks with teacher's editions have the appropriate bar codes printed in the margins. Publishers are increasingly including bar codes in their textbooks so that existing videodiscs can be used to provide a bridge between the world of the textbook and multimedia.

Another method for accessing frames on a videodisc uses the desktop computer as a controlling device. The integration of computers with this medium creates a multimedia experience that can be quite compelling, both in its content and in its capacity to support various learning styles. The GTV product from LucasArts and National Geographic is one example of this integrated approach that effectively marries the two media.

Most computer-based videodisc applications rely on two monitors—one for the computer images and another for the video images, but inexpensive accessories for personal computers are making it possible to show the video image in a window comprising part of the computer image. Adapters that provide this capability are available for all major computer platforms (Apple, IBM compatibles, Commodore Amiga) and are likely to become more popular as their prices drop. As of this writing, however, most computer-based videodisc systems use two monitors—a trend we see continuing throughout 1992.

Several states, such as Florida, Texas, and California, have adopted aggressive programs with respect to laser videodisc technology, and this field will continue to grow in popularity because of the following:

- Low cost. Players are available for well under $1000.
- Ease of use. Virtually no staff development is needed to show users how to operate this equipment, especially when the bar code reader is used.
- Increasing number of titles. Many ITV providers, including Coronet, National Geographic, ABC News Interactive, and The Discovery Channel, are making materials available in this format.

### b. CD-ROM and Related Technologies

#### i. CD-ROMs and Information Libraries

Another optical medium of importance to education is the CD-ROM, which uses discs similar in appearance to the music CDs that have virtually driven the vinyl record to extinction. Each of these 12 cm discs can hold about 650 megabytes of information—equivalent to almost 300,000 pages of text. The medium can contain text, computer software, digitized (as opposed to analog) video color images, and CD-quality sound. Information is accessed from these discs using special disc drives connected to personal computers.

The first applications for this medium were limited to reference materials (encyclopedias, collections of classical literature such as the *Library of the Future* from World Library Corp.[34], and the like). A student using a computer equipped with a CD-ROM has access to more information than was in the Vatican library at the height of the Renaissance.

Not surprisingly, CD-ROMs are finding their ways into school libraries where immediate access to informational databases is easily justified. There are two aspects of information searching in this environment that make this technology compelling in education.

1. The volume of information that can be stored on one disc is phenomenally large—the World Library disc mentioned above, for example, contains over 900 classical works of literature.

2. The searching methods supported by the host computer allow information to be found through a variety of means that are not feasible when using the printed record.

New CD-ROMs are expanding into full-fledged multimedia applications. The *Mammals* disc from National Geographic, for example, includes a database with pictures, animated sequences, and sounds from numerous mammals.[28] Furthermore, this disc supports numerous searching strategies, and includes some activities specifically geared to education. In another example of the power of this medium, Warner New Media is publishing a series of discs on classical music.[35] Their recording of Beethoven's *14th String Quartet*, for example, is accompanied by a computer program that provides a series of in-depth analyses of the music, along with a rich reference library on music complete with high-quality recordings used to illustrate various aspects of compositional style. Developments of this sort will ensure the growth of this medium in education for at least the next 5 years.

In November 1991, Sony released the Data Discman in the United States.[36] This hand-held CD-ROM device brings the power of desktop computer-based information retrieval into the world of the hand-held device. Data Discman supports text and limited graphics and retails, with several "electronic books," for under $500. This means that by the end of 1991 some of our students are carrying full reference libraries in their backpacks. The impact of this technology on education warrants close examination.

#### ii. CDTV and CD-I

The home market for information appliances is virtually untapped. Vendors such as Commodore, Sony, Phillips, and Pioneer are poised to bring the power of CD-ROM multimedia into dens and living rooms throughout America. To do this, they are providing self-contained information delivery systems that connect to televisions and sound systems as easily as VCRs and laser videodisc players. Because of their ease of use, their low cost, and their rich support for color graphics, CD-quality audio, and limited anima-

tion they are likely to have a strong effect on education.

CDTV, from Commodore[37], was the first technology of this genre to ship in quantity. The device resembles an audio CD player in appearance, but actually contains a complete Amiga computer system with a built-in CD-ROM drive. Users navigate through applications such as the Xiphias *Encyclopedia of Science and Technology*[38] disc using a hand-held controller similar to that found on video games. As with the laser videodisc players, CDTV can be mastered with little or no staff training.

CD-I is an international standard for interactive multimedia created in 1986 by a joint venture of N.V. Philips (Netherlands) and Sony and Matsushita (Japan). As with CDTV, CD-I was designed to be a consumer, stand-alone product rather than as a peripheral device for a computer system. The device contains a computer, of course, but, as with CDTV, the user perceives the CD-I system as providing specific functions (e.g., as a multimedia delivery system) rather than as a general-purpose device.

Introduction of CD-I has been delayed by the absence of high-quality video animation capability, but a product has been introduced with the capacity for full-screen, full-motion video upgrades to be installed later. As with CDTV, CD-I systems will retail for under $1000.[39] If this technology succeeds in the consumer marketplace, the education market will benefit from lower prices and the ubiquity of these systems, just as with VCR's and other consumer electronic products.

One benefit of the CD-I device is its compatibility with the Kodak Photo CD technology to be introduced in 1992.[40] One-hour photo labs will acquire the technology needed to transfer very high-resolution copies of 35mm slides or negatives to CD-ROMs very inexpensively. Each disc will have the capacity to hold 100 full-color images that can be accessed through remote controls—effectively allowing students and teachers to create still-frame custom videodiscs at their corner photo shop.

As with CDTV, the success of CD-I is in the hands of software developers. If sufficiently compelling programs are created, the sales of these machines will ensure a viable market for the foreseeable future. If, however, the manufacturers have misread the desire of the general public to interact with their entertainment devices, the benefits of these technologies may be lost to education as the education market is unlikely to be strong enough to support these technologies on its own.

## Telecommunications

### a. Telephones

We should be astonished to find that, still today, telephones are virtually absent from classrooms. This absence effectively isolates the classroom from active communication with the rest of the world. In those rare cases where telephones do exist, and when these telephones are connected to computers with telecommunications capabilities, the educational benefits are spectacular. To cite one example, Apple Global Education (AGE) is a project connecting students and teachers around the world.[41] This network provides opportunities for free-form discussion of any topic of interest to the participants, and has resulted in a vast number of solid curricular projects in the past two years.

Given the number of global transformations we have recently experienced—the destruction of the Berlin wall, Operation Desert Storm, and the more recent activities in the Soviet Bloc countries—there is a steady stream of global topics to interest students in all countries. Discussions of more mundane topics—preferences in music, parental rules for staying out at night, and so on—forge friendships as students share perspectives with their peers in other nations. The impact of projects of this sort on student interest in geography, history, current events, language, and culture is profound.

Educators connected to projects like this have a forum for discussing topics of interest to them as well as resources for lesson ideas. Projects abound and anyone with a personal computer and a modem has virtually unlimited access to bulletin-boards devoted to education—often for little more than the cost of a local phone call.

None of this is available from the classroom, however, unless it contains a telephone line to the outside world. At a time when many homes are adding second lines for fax machines and the like, the absence of telephones in our classrooms is a reminder of the 19th century mentality underlying much of education in our country.

### b. Fiber Optics and ISDN

Computer communication over voice-grade telephone lines is a lot like sucking peanut butter up a soda straw. Computers are designed to move data at a rate many times that supported by copper telephone wires. As the phone companies replace copper wire with fiber optics, we will be able to increase data communication rates.

One standard for increased data rates is provided by ISDN (Integrated Services Digital Network).[42] This protocol supports increased communications capability for computers, thus magnifying the impact of telecommunications projects. This improvement in capability comes at increased cost, however, and it remains to be seen what these services mean for the classrooms of our country. We should not wait for these services, but should continue to expand our current use of voice-grade telecommunications in the classroom until such time as ISDN has proven its benefits for education.

### c. Cable

According to the EIA report cited previously, about 60 percent of our homes are presently connected to cable systems, and this percentage is increasing by several percent a year. Because over 85 percent of the homes in the United States are passed by cable, this technology has the capacity to become ubiquitous in the next few years.[43]

The growth in cable hookups is increasing the market for special interest programming, including a host of educational offerings. The Discovery and Arts & Entertainment channels often provide excellent educational programs rivaling those found on local PBS stations. Discovery's affiliate, The Learning Channel, is geared primarily to the delivery of instructional programming. This recent acquisition from Financial News Network indicates Discovery's commitment to educational programming.

Mind Extension University (ME/U) is a long-distance cable-based learning service launched by Jones Intercable in 1987. ME/U hit the 9 million subscriber mark last year with the addition of 450,000 part-time subscribers in the Seattle area.[44] The service also has acquired its first interactive high school classroom, in Bement, Illinois, through its relationship with the TI-IN Network.

The service's 800 number, which serves as the entry to all ME/U services—including registration, book ordering, and, in the case of the M.B.A. program, voice mailboxes for students and professors—receives an average of 400 to 500 calls per day.

Unlike telephone lines, free cable hookups are available to many schools. In addition to providing free access to basic cable service, some providers also include newswire services that can be accessed by personal computers.[45] This service, X•Press X•Change, allows users to capture items of interest ranging from the latest news stories from around the world to complete lesson plans and public domain software.

None of this will have an influence, however, if educators are unaware of their access to these services, or if they choose to ignore the capability this technology provides.

### d. Satellite

Satellite use in education is often connected with the delivery of courses for students and teachers. For example, ESD 101 in Spokane, Washington, provides courses in Calculus, Russian, and other subjects for schools unable to provide these courses on their campuses.[46] Students view live broadcasts from a remote studio, and can contact the teacher through a special telephone number hooked up in the broadcast studio. Assignments are sent to the station for grading and then sent back to the various schools for distribution to the students. Similarly, The Star Schools Program, created by Public Law 100-297, brought courses in science, math and language to over 12,000 students in isolated and small schools throughout the United States in the 1989-1990 school year.[47] This U.S. DOE-funded program incorporates a variety of telecommunication technologies, including satellites and phone lines.

While this technology provides an efficient delivery system for classes, it lacks the spontaneity and interactivity of face-to-face teaching. Some of this stems from the fact that, while the teacher sends both video and sound, the return path is voice only. These systems don't allow the student to "come to the blackboard" or interact closely with other students at their locations. The result is that many of these courses are presented in a didactic manner that does not take into account individual learning styles. As telecommunications bandwidth increases, and image compression technology improves, one can envision full two-way video links that make the experience more like that of a classroom.[48] In the meantime, the main benefit of this technology is its capacity to provide courses that would otherwise be unavailable in some schools, a benefit that far outweighs any of the drawbacks.

Another potentially important aspect of satellite broadcast for classroom use will come from a technology designed to compete with cable—DBS (direct broadcast satellite).[49] This technology allows any facility equipped with a small (approximately 1 meter) antenna to receive over 100 channels of television—greatly expanding the options available from cable systems. This low-cost technology (expected to retail for about $300) should be available by 1994 and deserves close attention.

### e. Microwave

Microwave narrowcasting provides high-bandwidth communications between two locations for those activities not requiring the capabilities of satellite broadcasts. In one of the more spectacular uses of line-of-sight microwave communications, visitors to the Monterey Bay Aquarium[50] are able to see live broadcasts from the MBARI research vessel exploring the depths of the Monterey Canyon. A marine biologist in a theater at the aquarium describes the color video images being sent from the depths of the ocean to an audience of hundreds. This audience is treated to a view of scientific discovery as it happens—often seeing new species at the moment of discovery.

One can imagine other educationally relevant uses for line-of-sight high-bandwidth communications. For example, satellite broadcast of courses can use microwave "return" paths to allow video from the various school sites, as long as they are within line of sight of the receiving antenna.

### Virtual Reality

No document on educational technology for the 90s would be complete without some mention of developments in the area of virtual reality. This term is applied to technologies that create simulations of visual, auditory, and tactile spaces that are so compelling that they actually trick the senses into believing that the experience of exploring these domains is real.[51] One example of virtual reality that may be familiar to some readers is the Star Tours exhibit at Disneyland—a simulated journey into space created by LucasArts. The kinesthetic and visual experience afforded by this attraction makes it feel like a roller coaster though the participant never actually moves from the starting location of the ride.

Another example of virtual reality can be found at the local game arcade. Sega's Time Traveler game uses a parabolic mirror projection system to create a virtual image that hangs in front of the viewer, much like a 3-D image. This display technology, created by Micro•Theater[52], promises to raise the ante in the world of video, making the blackboard look more and more like a 19th century relic.

Interactive virtual reality products often incorporate head-mounted 3-D displays and "gesture gloves" or other tools that allow users to navigate through a computed world constructed on the display. Surgeons, for example, can navigate through a computerized model of a patient's brain to select the best approach for removing a tumor. Architects can "tour" buildings before they are built, change the locations of windows and doors by grabbing them and moving them around in this artificial reality, and then instruct the computer to create a new set of drawings reflecting these changes.

The technology of virtual reality is in its infancy, so it is too soon to tell what effect it will have on education. However, Autodesk—a leader in this field—is allowing educators and students to explore these tools to see how they might best be used.[53]

## How Will Federal and State Telecommunications Policy Decisions Affect Education's Access to These Technologies?

Federal and state policy can enable access to technology, but advances in this area must be accompanied by an educational campaign that brings knowledge of technological developments to teachers. For example, cable providers like TCI provide free hookups and basic cable service to each school in the districts they serve. TCI's commitment extends to the provision of up to two free hookups per school to X•Press, the cable-based access to international newswire services mentioned in the previous section.[45] All of this is free to the school, but an informal telephone survey has shown that few schools are aware of their access to these services, or that they have yet to understand the enormous educational benefits such services provide.

In 1982, Apple Computer wanted to donate a computer to every school in the nation, but legislation that would have provided deductibility beyond parts cost failed to clear the federal legislative process.[54] California did pass the enabling legislation, thus allowing Apple to donate over 9000 complete computer systems to schools in 1983. While many of these computers were used effectively, some were not. This once again highlights the need to make educators aware of the benefits of technology. It seems important to ensure that, as legislation paves the way for increased use of technology in the classroom, provision is made to provide meaningful education on both the availability and use of this technology to all teachers. Access is meaningful only to those who understand its implications.

There are areas where federal and state policy can have a positive influence on access and use of educational technology. The first of these is access to telephones in every classroom. The equipment itself is not the problem. The real challenge is in access to the lines. If schools are charged business rates for telephone hookups, the monthly cost of equipping

each classroom with an outside line would be prohibitive. If, on the other hand, the RBOC's can be enticed to provide basic service at no monthly charge beyond the cost of the calls themselves, the barrier to universal access to phones in the classroom would be greatly lowered. The immediate benefit of this would be increased access to remote databases and telecommunication projects of the sort described in the previous section.

Government policy on safety in the workplace has the capacity to ensure that the computer workstations used in classrooms are safe to use. Some communities, like San Francisco, California, have been particularly aggressive on the issue of safety, and other communities are following suit.

Policy regarding satellite, microwave, and other high-bandwidth communication tools (e.g., ISDN) are being driven by the needs of industry. Schools will be the beneficiaries of developments in this area.

The FCC's role as guardian of the airwaves also benefits education through its support of the KidVid law and requirement that stations meet community needs.[55]

While money alone will not address all the challenges facing education, it seems that one way federal and state policy can positively affect schools is to provide both money and incentives to bring technology into the hands of every student. For example, every student could be provided with a personal notebook computer, which cost about $100 each—amounting to about $10 billion dollars for a nation of 100 million children. While this amount may seem staggering at first glance, it pales in comparison to the expense of the S&L bailout. Much of our policy seems devoted to the repair of social situations that have gotten out of control, rather than toward the more modest expenditure of money in prevention of problems.

Policy regarding educational funding needs to undergo a significant revision if we are to meet the needs of today's students. One way state policy can be helpful is by allowing states to spend "textbook" money on a mix of educational technologies that are emerging as alternatives to textbooks. Some states, like Texas, have moved in this direction, and this decision will help to accelerate the effective incorporation of technology into mainstream education.

## CHANGES

*We do not teach people to drive cars by having them ride bicycles.*
Allan Collins

### What Changes in the Classroom are Necessary to Create the New Learning Environments?

#### Attitudinal changes

Many educators fail to use available educational technology. The reasons for this are complex and varied, but many of them can be addressed through effective staff development programs that provide concrete connections between solid pedagogical ideas, local curricular frameworks, and technologies. Unless these staff development programs are made available to all educators, the promise of educational technology will fail to be realized.

There remains the challenge of those educators, administrators, and school board members who fail to see any place for modern technology in the classroom. Far from being passive in their reluctance, some of these neo-Luddites are actively opposed to anything that challenges the primacy of the textbook and lecture in education. This challenge has been faced once before—with the growth of the printed book in the Middle Ages.[56-58] It took several hundred years for the mass-produced book to be accepted in education but we must not make the same mistake with regard to acceptance of technology in our classrooms.

Industry adopts effective technologies as a survival mechanism in an increasingly fast-paced competitive world, yet educators are sometimes dealt the one-two punch of scarce funding and negative attitudes when it comes to bringing technology to our students. Unless we take rapid and positive action to create a broader base of support for educational technologies, we risk the perpetuation of an outmoded school system.

Our homes are rapidly becoming rich repositories and windows into the world of information—at least for our affluent urban population. It is a short step from access to a collapse of public schools as parents realize that solid educational content can be delivered over the airwaves, and through interactive technologies. The fact that these media supplement rather than displace the teacher may be lost on those



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who see continued resistance to technology use in the public schools. The debate currently raging on topics like choice, for example, is likely to intensify unless radical changes are made in our approaches to education. One need look no further than Brazil to see the devastation of public schooling that can result when affluent families pull their children out of public schools.[59]

The equity of access that has characterized our public system is being threatened from within by those who fail to accept that the technologies of the Information Age are not fads but they are the productivity tools of the 21st century. We must address this issue with all our vigor or risk damaging public education in our country.

### Organizational changes

The structure of the traditional six-period day is better suited to teacher-based didactic presentation than to a more student-centered approach to learning. School sites should be free to experiment with extended periods to allow more in-depth exploration of content. Other educational models, such as integrated thematic curricula, afford possibilities to make education engaging to all learners. These and other approaches should be freely chosen by educators on a site-by-site basis. While the move toward site-based management is positive, it is unlikely that it will have any lasting positive effect if the decision makers at the site are unaware of the various options available to them. Toward this end, it is essential that, as power shifts to the site, educators are provided with opportunities to learn about various restructuring models so they can make informed choices.

Insofar as technology is concerned, release time is essential if educators are to master the use of informational tools. In addition to increased release time to attend educational technology conferences, technology-using educators need to be able to work with their peers to share their knowledge on the practical uses of these tools in classrooms. Fortunately, effective models for on-site technology training exist.[60] The challenge is finding effective ways to disseminate these models to all schools in the country.

### Facilities Changes

Many of our schools are falling apart. Many thousands of children are housed in trailers as school enrollments have outraced the community's ability (or willingness) to build new schools. Assuming that the public will provide the resources needed to bring our schools into good physical condition, we will have an opportunity to design and build schools in ways that acknowledge technological advances beyond the slate chalkboard. For example, every classroom should have sufficient electrical outlets to support universal access to computers. This means at least a duplex outlet at each desk with provision for network cabling. The teacher's work area needs to be supported by at least six outlets to support a computer, printer, laser videodisc, VCR, and other audio-visual equipment needed in the classroom. Because it is not likely that rearview color projection systems will be placed in schools because of space constraints, minimal provision should be secured for ceiling mounted video projectors. This requires sufficiently strong ceiling beams to support a color video projector, a ceiling-mounted power outlet, and a cable race to bring the video signal from the teacher's work center to the projector. The description just provided represents a minimal implementation and can be enhanced for those educators wanting to use additional technologies.

The 16mm projector has become an anachronism. The blackboard may be the next to go. An appropriate compromise in classrooms for the next decade would be to have chalkboard panels on either side of a high-gain projection screen. This would allow educators to supplement their use of instructional technology with traditional hand-written comments.

### How Can These Changes be Made?

For the vast majority of teachers, the two issues limiting technology use will be access and education. Of these, education must be addressed first. Rapid changes on the technological horizon suggest that, unless educators first understand the utility of the devices being brought into their classrooms, the technology risks becoming outdated while teachers try to figure out how (or why) to use it. This suggests that intensive staff development on the proper uses of educational technology must become a high national priority.

Once educators understand both why and how technology enhances the educational process, access to this technology needs to be provided—along with sufficient release time for educators to restructure lessons in ways that take advantage of these tools.

Both education and access are continuing, rather than one-shot, issues. Therefore, staff development in these areas needs to be ongoing, just as it is in industry. The cost of doing this job properly is minuscule compared to the cost of lost opportunity to our nation if we fail to properly equip students for life in the 21st century.

## RECOMMENDATIONS

Because existing technologies are continuing to undergo rapid change, and new educational technologies appear on the horizon with great regularity, it is recommended that educational technology policy remain flexible to accommodate new technologies as they become available. In order to maximize the benefit of new technologies in the foreseeable future, it is recommended that:

- Regular reports are generated and widely disseminated to apprise education policymakers and decision makers about new and forthcoming technologies.
- Educational technology budgets maintain flexibility so that purchasers are free to explore new technologies as they appear.
- States continue to fund model technology projects with school districts and software developers to help incorporate the latest advances in technology with existing state curriculum frameworks, much as California is doing.
- Staff development programs bring educators up to date on all aspects of educational technology, providing not only awareness, but access to these technologies for incorporation into the classroom. This needs to start in our preservice programs, but must be supplemented by annual updates in keeping with the rapid growth of technology.
- Some provision be made for multi-state credentials for educators using distance-learning tools (satellites, and so on). This will become increasingly important as two-way video conferencing moves us beyond the realm of the "talking heads" presentations facilitated by today's satellite systems. One example of the challenges facing us in this area is the question of whether Dr. Carl Sagan should be allowed to "teach" astronomy to our K-12 students, even though he is not a credentialed teacher.
- The issue of fair use of copyrighted information for classroom use needs to be addressed, especially the repurposing of video in multimedia projects. Many teachers operate in total ignorance of copyright laws, freely showing recorded television broadcasts to their students, and freely allowing students to incorporate clips of copyrighted video materials into their own reports. Even the digitizing of images from videodiscs for inclusion in computer-based hypermedia reports may violate some information providers' copyrights. Rather than address these issues, many educators argue that their use of these materials is educational, which means they are free to do what they want.

  While this argument may have merit, it runs counter to a strict interpretation of the law so the whole notion of "fair use" needs to be addressed. The fact is that much of copyright law was drafted prior to the advent of modern informational technology. The place for discussion about fair use is a venue that supports collaborative rather than adversarial proceedings. The longer we wait, the greater the risk that adversarial proceedings will strongly hamper effective, rational discussion of this topic.

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## APPENDIXES

The following two appendixes constitute opinions from the past on the effect of technology on education. The first, "As We May Think," was written by President Roosevelt's science advisor, Vannevar Bush. This article appeared in *Atlantic Monthly* in 1945 and constitutes an uncanny perspective on what we today would call a "hypermedia workstation." An annotated hypertext version of this document is available from Dr. Thornburg. The second article, "Classroom Without Walls," was composed by Marshall McLuhan in 1957. It describes a perspective on the effect of technology in education that is perhaps more relevant today than it was over 30 years ago when it was first published.

# As We May Think

Vannevar Bush

July, 1945

Of what lasting benefit has been man's use of science and of the new instruments which his research brought into existence? First, they have increased his control of his material environment, They have improved his food, his clothing, his shelter; they have increased his security and released him partly from the bondage of bare existence. They have given him increased knowledge of his own biological processes so that he has had a progressive freedom from disease and an increased span of life. They are illuminating the interactions of his physiological and psychological functions, giving promise of an improved mental health.

Science has provided the swiftest communication between individuals; it has provided a record of ideas and has enabled man to manipulate and to make extracts from that record so that knowledge evolves and endures throughout the life of a race rather than that of an individual.

There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends. The investigator is staggered by the findings and conclusions of thousands of other workers—conclusions which he cannot find time to grasp, much less to remember, as they appear. Yet specialization becomes increasingly necessary for progress, and the effort to bridge between disciplines is correspondingly superficial.

Professionally, our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purposes. If the aggregate time spent in writing scholarly works and in reading them could be evaluated, the ratio between these amounts of time might well be startling. Those who conscientiously attempt to keep abreast of current thought, even in restricted fields, by close and continuous reading might well shy away from an examination calculated to show how much of the previous month's efforts could be produced on call. Mendel's concept of the laws of genetics was lost to the world for a generation because his publication did not reach the few who were capable of grasping and extending it; and this sort of catastrophe is undoubtedly being repeated all about us, as truly significant attainments become lost in the mass of the inconsequential.

The difficulty seems to be not so much that we publish unduly in view of the extent and variety of present-day interests, but rather that publication has been extended far beyond our present ability to make real use of the record. The summation of human experience is being expanded at a prodigious rate, and the means we use for threading through the consequent maze to the momentarily important item is the same as was used in the days of square-rigged ships.

But there are signs of a change as new and powerful instrumentalities come into use. Photocells capable of seeing things in a physical sense, advanced photography which can record what is seen or even what is not, thermionic tubes capable of controlling potent forces under the guidance of less power than a mosquito uses to vibrate his wings, cathode ray tubes rendering visible an occurrence so brief that by comparison a microsecond is a long time, relay combinations which will carry out involved sequences of movements more reliably than any human operator and thousands of times as fast—there are plenty of mechanical aids with which to effect a transformation in scientific records.

Two centuries ago Leibnitz invented a calculating machine which embodied most of the essential features of recent keyboard devices, but it could not then come into use. The economics of the situation were against it: the labor involved in constructing it, before the days of mass production, exceeded the labor to be saved by its use, since all it could accomplish could be duplicated by sufficient use of pencil and paper. Moreover, it would have been subject to frequent breakdown, so that it could not have been depended upon; for at that time and long after, complexity and unreliability were synonymous.

Babbage, even with remarkably generous support for his time, could not produce his great arithmetical machine. His idea was sound enough, but construction and maintenance costs were then too heavy. Had a Pharaoh been given detailed and explicit designs of an automobile, and had he understood them completely, it would have taxed the resources of his kingdom to have fashioned the thousands of parts for a single car, and that car would have broken down on the first trip to Giza.

Machines with interchangeable parts can now be constructed with great economy of effort. In spite of much complexity, they perform reliably.
Witness the humble typewriter, or the movie camera, or the automobile. Electrical contacts have ceased to stick—note the automatic telephone exchange, which has hundreds of thousands of such contacts, and yet is reliable. A spider web of metal, sealed in a thin glass container, a wire heated to a brilliant glow, in short,

thermionic tube of radio sets, is made by the hundred million, tossed about in packages, plugged into sockets—and it works! Its gossamer parts, the precise location and alignment involved in its construction, would have occupied a master craftsman of the guild for months; now it is built for thirty cents. The world has arrived at an age of cheap complex devices of great reliability; and something is bound to come of it.

## The Silver Image

A record, if it is to be useful to science, must be continuously extended, it must be stored, and above all it must be consulted. Today we make the record conventionally by writing and photography, followed by printing; but we also record on film, on wax disks, and on magnetic wires. Even if utterly new recording procedures do not appear, these present ones are certainly in the process of modification and extension.

Certainly progress in photography is not going to stop. Faster material and lenses, more automatic cameras, finer-grained sensitive compounds to allow an extension of the minicamera idea, are all imminent. Let us project this trend ahead to a logical, if not inevitable, outcome. The camera hound of the future wears on his forehead a lump a little larger than a walnut. It takes pictures 3 millimeters square, later to be projected or enlarged, which after all involves only a factor of 10 beyond present practice. The lens is of universal focus, down to any distance accommodated by the unaided eye, simply because it is of short focal length. There is a built-in photocell on the walnut such as we now have on at least one camera, which automatically adjusts exposure for a wide range of illumination. There is film in the walnut for a hundred exposures, and the spring for operating its shutter and shifting its film is wound once and for all when the film clip is inserted. It produces its result in full color. It may well be stereoscopic, and record with two spaced glass eyes, for striking improvements in stereoscopic techniques are just around the corner.

The cord which trips its shutter may extend down a man's sleeve within easy reach of his fingers. A quick squeeze, and the picture is taken. On a pair of ordinary glasses is a square of fine lines near the top of one lens, where it is out of the way of ordinary vision. When an object appears in that square, it is lined up for its picture. As the scientist of the future moves about the laboratory or the field, every time he looks at something worthy of the record, he trips the shutter and in it goes, without even an audible click. Is this all fantastic? The only fantastic thing about it is the idea of making as many pictures as would result from its use.

Will there be dry photography? It is already here in two forms. When Brady made his Civil War pictures, the plate had to be wet at the time of exposure. Now it has to be wet during development instead. In the future, perhaps it need not be wetted at all. There have long been films impregnated with diazo dyes which form a picture without development, so that it is already there as soon as the camera has been operated. An exposure to ammonia gas destroys the unexposed dye, and the picture can then be taken out into the light and examined. The process is now slow, but someone may speed it up, and it has no grain difficulties such as now keep photographic researchers busy. Often it would be advantageous to be able to snap the camera and to look at the picture immediately.

Another process now in use is also slow, and more or less clumsy. For fifty years impregnated papers have been used which turn dark at every point where an electrical contact touches them, by reason of the chemical change thus produced in an iodine compound included in the paper. They have been used to make records, for a pointer moving across them can leave a trail behind. If the electrical potential on the pointer is varied as it moves, the line becomes light or dark in accordance with the potential.

This scheme is now used in facsimile transmission. The pointer draws a set of closely spaced lines across the paper one after another. As it moves, its potential is varied in accordance with a varying current received over wires from a distant station, where these variations are produced by a photocell which is similarly scanning a picture. At every instant the darkness of the line being drawn is made equal to the darkness of the point on the picture being observed by the photocell. Thus, when the whole picture has been covered, a replica appears at the receiving end.

A scene itself can be just as well looked over line-by-line by the photocell in this way as can a photograph of the scene, This whole apparatus constitutes a camera, with the added feature, which can be dispensed with if desired, of making its picture at a distance. It is slow, and the picture is poor in detail. Still, it does give another process of dry photography, in which the picture is finished as soon as it is taken.

It would be a brave man who would predict that such a process will always remain clumsy, slow, and faulty in detail. Television equipment today transmits sixteen reasonably good pictures a second, and it involves only two essential differences from the pro-

cess described above. For one, the record is made by a moving beam of electrons rather than a moving pointer, for the reason that an electron beam can sweep across the picture very rapidly indeed. The other difference involves merely the use of a screen which glows momentarily when the electrons hit, rather than a chemically treated paper or film which is permanently altered. This speed is necessary in television, for motion pictures rather than stills are the object.

Use chemically treated film in place of the glowing screen, allow the apparatus to transmit one picture only rather than a succession, and use a rapid camera for dry photography. The treated film needs to be far faster in action than present examples, but it probably could be. More serious is the objection that this scheme would involve putting the film inside a vacuum chamber, for electron beams behave normally only in such a rarefied environment. This difficulty could be avoided by allowing the electron beam to play on one side of a partition, and by pressing the film against the other side, if this partition were such as to allow the electrons to go through perpendicular to its surface, and to prevent them from spreading out sideways. Such partitions, in crude form, could certainly be constructed, and they will hardly hold up the general development.

Like dry photography, microphotography still has a long way to go. The basic scheme of reducing the size of the record, and examining it by projection rather than directly, has possibilities too great to be ignored. The combination of optical projection and photographic reduction is already producing some results in microfilm for scholarly purposes, and the potentialities are highly suggestive. Today, with microfilm, reductions by a linear factor of 20 can be employed and still produce full clarity when the material is re-enlarged for examination. The limits are set by the graininess of the film, the excellence of the optical system, and the efficiency of the light sources employed. All of these are rapidly improving.

Assume a linear ratio of 100 for future use. Consider film of the same thickness as paper, although thinner film will certainly be usable. Even under these conditions there would be a total factor of 10,000 between the bulk of the ordinary record in books and its microfilm replica, The Encyclopaedia Britannica could be reduced to the volume of a matchbox. The library of a million volumes could be compressed into one end of a desk. If the human race has produced since the invention of movable type a total record, in the form of magazines, newspapers, books, tracts, advertising blurbs, correspondence, having a volume corresponding to a billion books, the whole affair, assembled and compressed, could be lugged off in a moving van. Mere compression, of course, is not enough; one needs not only to make and store a record but also be able to consult it, and this aspect of the matter comes later. Even the modern great library is not generally consulted; it is nibbled at by a few.

Compression is important, however, when it comes to costs. The material for the microfilm Britannica would cost a nickel, and it could be mailed anywhere for a cent. What would it cost to print a million copies? To print a sheet of newspaper, in a large edition, costs a small fraction of a cent. The entire material of the Britannica in reduced microfilm form would go on a sheet eight and one-half by eleven inches. Once it is available, with the photographic reproduction methods of the future, duplicates in large quantities could probably be turned out for a cent apiece beyond the cost of materials. The preparation of the original copy? That introduces the next aspect of the subject.

## Vocoder

To make the record, we now push a pencil or tap a typewriter. Then comes the process of digestion and correction, followed by an intricate process of typesetting, printing, and distribution. To consider the first stage of the procedure, will the author of the future cease writing by hand or typewriter and talk directly to the record? He does so indirectly, by talking to a stenographer or a wax cylinder; but the elements are all present if he wishes to have his talk directly, produce a typed record. All he needs to do is to take advantage of existing mechanisms and to alter his language.

At a recent World Fair a machine called a Voder was shown. A girl stroked its keys and it emitted recognizable speech. No human vocal cords entered into the procedure at any point; the keys simply combined some electrically produced vibrations and passed these on to a loudspeaker. In the Bell Laboratories there is the converse of this machine, called a Vocoder. The loudspeaker is replaced by a microphone, which picks up sound. Speak to it, and the corresponding keys move. This may be one element of the postulated system.

The other element is found in the stenotype, that somewhat disconcerting device encountered usually at public meetings. A girl strokes its keys languidly and looks about the room and sometimes at the speaker with a disquieting gaze. From it emerges a typed strip which records in a phonetically simplified language a record of what the speaker is supposed to have said. Later this strip is retyped into ordinary language, for in its nascent form it is intelligible only to the initiated. Combine these two elements, let the

Vocoder run the stenotype, and the result is a machine which types when talked to.

Our present languages are not especially adapted to this sort of mechanization, it is true. It is strange that the inventors of universal languages have not seized upon the idea of producing one which better fitted the technique for transmitting and recording speech. Mechanization may yet force the issue, especially in the scientific field; whereupon scientific jargon would become still less intelligible to the layman.

One can now picture a future investigator in his laboratory. His hands are free, and he is not anchored. As he moves about and observes, he photographs and comments. Time is automatically recorded to tie the two records together. If he goes into the field, he may be connected by radio to his recorder. As he ponders over his notes in the evening, he again talks his comments into the record. His typed record, as well as his photographs, may both be in miniature, so that he projects them for examination.

Much needs to occur, however, between the collection of data and observations, the extraction of parallel material from the existing record, and the final insertion of new material into the general body of the common record. For mature thought there is no mechanical substitute. But creative thought and essentially repetitive thought are very different things. For the latter there are, and may be, powerful mechanical aids.

## Napier's Bones Revisited

Adding a column of figures is a repetitive thought process, and it was long ago properly relegated to the machine. True, the machine is sometimes controlled by a keyboard, and thought of a sort enters in reading the figures and poking the corresponding keys, but even this is avoidable. Machines have been made which will read typed figures by photocells and then depress the corresponding keys; these are combinations of photocells for scanning the type, electric circuits for sorting the consequent variations, and relay circuits for interpreting the result into the action of solenoids to pull the keys down.

All this complication is needed because of the clumsy way in which we have learned to write figures. If we recorded them positionally, simply by the configuration of a set of dots on a card, the automatic reading mechanism would become comparatively simple. In fact, if the dots are holes, we have the punched-card machine long ago produced by Hollorith for the purposes of the census, and now used throughout business. Some types of complex businesses could hardly operate without these machines.

Adding is only one operation. To perform arithmetical computation involves also subtraction, multiplication, and division, and in addition some method for temporary storage of results, removal from storage for further manipulation, and recording the final results by printing. Machines for these purposes are now of two types: keyboard machines for accounting and the like, manually controlled for the insertion of data, and usually automatically controlled as far as the sequence of operations is concerned; and punched-card machines in which separate operations are usually delegated to a series of machines, and the cards then transferred bodily from one to another. Both forms are very useful; but as far as complex computations are concerned, both are still in embryo.

Rapid electrical counting appeared soon after the physicists found it desirable to count cosmic rays. For their own purposes the physicists promptly constructed thermionic-tube equipment capable of counting electrical impulses at the rate of 100,000 a second. The advanced arithmetical machines of the future will be electrical in nature, and they will perform at 100 times present speeds, or more.

Moreover, they will be far more versatile than present commercial machines, so that they may readily be adapted for a wide variety of operations. They will be controlled by a control card or film, they will select their own data and manipulate it in accordance with the instructions thus inserted, they will perform complex arithmetical computations at exceedingly high speed, and they will record results in such form as to be readily available for distribution or for later further manipulation. Such machines will have enormous appetites. One of them will take instructions and data from a whole roomful of people armed with simple keyboard punches, and will deliver sheets of computed results every few minutes. There will always be plenty of things to compute in the detailed affairs of millions of people doing complicated things.

The repetitive processes of thought are not confined, however, to matters of arithmetic and statistics. In fact, every time one combines and records facts in accordance with established logical processes, the creative aspect of thinking is concerned only with the selection of the data and the process to be employed, and the manipulation thereafter is repetitive in nature and hence a fit matter to be relegated to the machines. Not so much has been done along these lines, beyond the bounds of arithmetic, as might be done, primarily because of the economics of the situation. The needs of business, and the extensive market obviously waiting, assured the advent of mass-produced arithmetical machines just as soon as production methods were sufficiently advanced.

With machines for advanced analysis, no such situation existed; for there was and is no extensive market; the users of advanced methods of manipulating data are a very small part of the population. There are, however, machines for solving differential equations—and functional and integral equations, for that matter. There are many special machines, such as the harmonic synthesizer which predicts the tides. There will be many more, appearing certainly first in the hands of the scientist and in small numbers.

If scientific reasoning were limited to the logical processes of arithmetic, we should not get far in our understanding of the physical world. One might as well attempt to grasp the game of poker entirely by the use of the mathematics of probability. The abacus, with its beads strung on parallel wires, led the Arabs to positional numerations and the concept of zero many centuries before the rest of the world; and it was a useful tool —so useful that it still exists.

It is a far cry from the abacus to the modern keyboard accounting machine. It will be an equal step to the arithmetical machine of the future. But even this new machine will not take the scientist where he needs to go. Relief must be secured from laborious detailed manipulation of higher mathematics as well, if the users of it are to free their brains for something more than repetitive detailed transformations in accordance with established rules. A mathematician is not a man who can readily manipulate figures; often he cannot. He is not even a man who can readily perform the transformations of equations by the use of calculus. He is primarily an individual who is skilled in the use of symbolic logic on a high plane, and especially he is a man of intuitive judgment in the choice of the manipulative processes he employs.

All else he should be able to turn over to his mechanic, just as confidently as he turns over the propelling of his car to the intricate mechanism under the hood. Only then will mathematics be practically effective in bringing the growing knowledge of atomistics to the useful solution of the advanced problems of chemistry, metallurgy, and biology. For this reason there will come more machines to handle advanced mathematics for the scientist. Some of them will be sufficiently bizarre to suit the most fastidious connoisseur of the present artifacts of civilization.

### The Perpetual Auditor

The scientist, however, is not the only person who manipulates data and examines the world about him by the use of logical processes, although he sometimes preserves this appearance by adopting into the fold anyone who becomes logical, much in the manner in which a British labor leader is elevated to knighthood. Whenever logical processes of thought are employed—that is, whenever thought for a time runs along an accepted groove—there is an opportunity for the machine. Formal logic used to be a keen instrument in the hands of the teacher in his trying of students' souls. It is readily possible to construct a machine which will manipulate premises in accordance with formal logic, simply by the clever use of relay circuits. Put a set of premises into such a device and turn the crank, and it will readily pass out conclusion after conclusion, all in accordance with logical law, and with no more slips than would be expected by a keyboard adding machine.

Logic can become enormously difficult, and it would undoubtedly be well to produce more assurance in its use. The machines for higher analysis have usually been equation solvers. Ideas are beginning to appear for equation transformers, which will rearrange the relationship expressed by an equation in accordance with strict and rather advanced logic. Progress is inhibited by the exceedingly crude way in which mathematicians express their relationships. They employ a symbolism which grew like Topsy and has little consistency; a strange act in that most logical field.

A new symbolism, probably positional, must apparently precede the reduction of mathematical transformations to machine processes. Then, on beyond the strict logic of the mathematician, lies the application of logic in everyday affairs. We may some day click off arguments on a machine with the same assurance that we now enter sales on a cash register. But the machine of logic will not look like a cash register, even of the streamlined model.

So much for the manipulation of ideas and their insertion into the record. Thus far we seem to be worse off than before—for we can enormously extend the record; yet even in its present bulk we can hardly consult it. This is a much larger matter than merely the extraction of data for the purposes of scientific research; it involves the entire process by which man profits by his inheritance of acquired knowledge. The prime action of use is selection, and here we are halting indeed. There may be millions of fine thoughts, and the account of the experience on which they are based, all encased within stone walls of acceptable architectural form; but if the scholar can get at only one a week by diligent search, his syntheses are not likely to keep up with the current scene.

Selection, in this broad sense, is a stone adze in the hands of a cabinetmaker. Yet, in a narrow sense and in other areas, something has already been done mechanically on selection. The personnel officer of a factory drops a stack of a few thousand employee

cards into a selecting machine, sets a code in accordance with an established convention, and produces in a short time a list of all employees who live in Trenton and know Spanish. Even such devices are much too slow when it comes for example, to matching a set of fingerprints with one of five million on file. Selection devices of this sort will soon be speeded up from their present rate of reviewing data at a few hundred a minute. By the use of photocells and microfilm they will survey items at the rate of a thousand a second, and will print out duplicates of those selected.

This process, however, is simple selection: It proceeds by examining in turn every one of a large set of items, and by picking out those which have certain specified characteristics. There is another form of selection best illustrated by the automatic telephone exchange. You dial a number and the machine selects and connects just one of a million possible stations. It does not run over them all. It pays attention only to a class given by a first digit, then only to a subclass of this given by the second digit, and so on; and thus proceeds rapidly and almost unerringly to the selected station. It requires a few seconds to make the selection, although the process could be speeded up if increased speed were economically warranted. If necessary, it could be made extremely fast by substituting thermionic-tube switching for mechanical switching, so that the full selection could be made in one one-hundredth of a second. No one would wish to spend the money necessary to make this change in the telephone system, but the general idea is applicable elsewhere.

Take the prosaic problem of the great department store. Every time a charge sale is made, there are a number of things to be done. The inventory needs to be revised, the salesman needs to be given credit for the sale, the general accounts need an entry, and, most important, the customer needs to be charged. A central records device has been developed in which much of this work is done conveniently. The salesman places on a stand the customer's identification card, his own card, and the card taken from the article sold —all punched cards. When he pulls a lever, contacts are made through the holes, machinery at a central point makes the necessary computations and entries, and the proper receipt is printed for the salesman to pass to the customer.

But there may be 10,000 charge customers doing business with the store, and before the full operation can be completed someone has to select the right card and insert it at the central office. Now rapid selection can slide just the proper card into position in an instant or two, and return it afterward. Another difficulty occurs, however. Someone must read a total on the card, so that the machine can add its computed item to it. Conceivably the cards might be of the dry photography type I have described. Existing totals could then be read by photocell, and the new total entered by an electron beam.

The cards may be in miniature, so that they occupy little space. They must move quickly. They need not be transferred far, but merely into position so that the photocell and recorder can operate on them. Positional dots can enter the data. At the end of the month a machine can readily be made to read these and to print an ordinary bill. With tube selection, in which no mechanical parts are involved in the switches, little time need be occupied in bringing the correct card into use—a second should suffice for the entire operation. The whole record on the card may be made by magnetic dots on a steel sheet if desired, instead of dots to be observed optically, following the scheme by which Poulsen long ago put speech on a magnetic wire. This method has the advantage of simplicity and ease of erasure. By using photography, However, one can arrange to project the record in enlarged form, and at a distance by using the process common in television equipment.

One can consider rapid selection of this form and distance projection for other purposes. To be able to key one sheet of a million before an operator in a second or two, with the possibility of then adding notes thereto, is suggested in many ways. It might even be of use in libraries, but that is another story. At any rate, there are now some interesting combinations possible. One might, for example, speak to a microphone, in the manner described in connection with the speech-controlled typewriter, and thus make his selections. It would certainly beat the usual file clerk.

## MEMEX

The real heart of the matter of selection, however, goes deeper than a lag in the adoption of mechanisms by libraries, or a lack of development of devices for their use. Our ineptitude in getting at the record is largely caused by the artificiality of systems of indexing. When data of any sort are placed in storage they are filed alphabetically or numerically, and information is found (when it is) by tracing it down from subclass to subclass. It can be in only one place, unless duplicates are used; one has to have rules as to which path will locate it, and the rules are cumbersome. Having found one item, moreover, one has to emerge from the system and re-enter on a new path.

The human mind does not work that way. It operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the

association of thoughts in accordance with some intricate web of trails carried by the cells of the brain. It has other characteristics, of course; trails that are not frequently followed are prone to fade, items are not fully permanent, memory is transitory. Yet the speed of action, the intricacy of trails, the detail of mental pictures, is awe-inspiring beyond all else in nature.

Man cannot hope fully to duplicate this mental process artificially, but he certainly ought to be able to learn from it. In minor ways he may even improve, for his records have relative permanency. The first idea, however, to be drawn from the analogy concerns selection. Selection by association, rather than by indexing, may yet be mechanized. One cannot hope thus to equal the speed and flexibility with which the mind follows an associative trail, but it should be possible to beat the mind decisively in regard to the permanence and clarity of the items resurrected from storage.

Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and, to coin one at random, "memex" will do. A memex is a device in which an individual stores his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.

It consists of a desk, and while it can presumably be operated from a distance, it is primarily the piece of furniture at which he works. On the top are slanting translucent screens, on which material can be projected for convenient reading. There is a keyboard, and sets of buttons and levers. Otherwise it looks like an ordinary desk.

In one end is the stored material. The matter of bulk is well taken care of by improved microfilm. Only a small part of the interior of the memex is devoted to storage, the rest to mechanism. Yet if the user inserted 5000 pages of material a day it would take him hundreds of years to fill the repository, so he can be profligate and enter material freely.

Most of the memex contents are purchased on microfilm ready for insertion. Books of all sorts, pictures, current periodicals, newspapers, are thus obtained and dropped into place, Business correspondence takes the same path. And there is provision for direct entry. On the top of the memex is a transparent platen. On this are placed longhand notes, photographs, memoranda, all sorts of things. When one is in place, the depression of a lever causes it to be photographed onto the next blank space in a section of the memex film, dry photography being employed.

There is, of course, provision for consultation of the record by the usual scheme of indexing. If the user wishes to consult a certain book, he taps its code on the keyboard, and the title page of the book promptly appears before him, projected onto one of his viewing positions. Frequently used codes are mnemonic, so that he seldom consults his code book; but when he does, a single tap of a key projects it for his use. Moreover, he has supplemental levers. On deflecting one of these levers to the right he runs through the book before him, each paper in turn being projected at a speed which just allows a recognizing glance at each. If he deflects it further to the right, he steps through the book 10 pages at a time; still further at 100 pages at a time. Deflection to the left gives him the same control backwards.

A special button transfers him immediately to the first page of the index. Any given book of his library can thus be called up and consulted with far greater facility than if it were taken from a shelf. As he has several projection positions, he can leave one item in position while he calls up another. He can add marginal notes and comments, taking advantage of one possible type of dry photography, and it could even be arranged so that he can do this by a stylus scheme, such as is now employed in the telautograph seen in railroad waiting rooms, just as though he had the physical page before him.

All this is conventional, except for the projection forward of present-day mechanisms and gadgetry. It affords an immediate step, however, to associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another. This is the essential feature of the memex. The process of tying two items together is the important thing.

When the user is building a trail, he names it, inserts the name in his code book, and taps it out on his keyboard. Before him are the two items to be joined, projected onto adjacent viewing positions. At the bottom of each there are a number of blank code spaces, and a pointer is set to indicate one of these on each item. The user taps a single key, and the items are permanently joined. In each code space appears the code word. Out of view, but also in the code space, is inserted a set of dots for photocell viewing; and on each item these dots by their positions designate the index number of the other item.

Thereafter, at any time, when one of these items is in view, the other can be instantly recalled merely by tapping a button below the corresponding code space. Moreover, when numerous items have been thus joined together to form a trail, they can be reviewed in turn, rapidly or slowly, by deflecting a lever like that used for turning the pages of a book. It

is exactly as though the physical items had been gathered together from widely separated sources and bound together to form a new book. It is more than this, for any item can be joined into numerous trails.

The owner of the memex, let us say, is interested in the origin and properties of the bow and arrow. Specifically, he is studying why the short Turkish bow was apparently superior to the English long bow in the skirmishes of the Crusades. He has dozens of possibly pertinent books and articles in his memex. First he runs through an encyclopedia, finds an interesting but sketchy article, leaves it projected. Next, in a history, he finds another pertinent item, and ties the two together. Thus he goes, building a trail of many items. Occasionally he inserts a comment of his own, either linking it into the main trail or joining it by a side trail to a particular item. When it becomes evident that the elastic properties of available materials had a great deal to do with the bow, he branches off on a side trail which takes him through textbooks on elasticity and tables of physical constants. He inserts a page of longhand analysis of his own. Thus he builds a trail of his interest through the maze of materials available to him.

And his trails do not fade. Several years later, his talk with a friend turns to the queer ways in which a people resist innovations, even of vital interest. He has an example, in the fact that the outranged Europeans still failed to adopt the Turkish bow. In fact, he has a trail on it. A touch brings up the code book. Tapping a few keys projects the head of the trail. A lever runs through it at will, stopping at interesting items, going off on side excursions. It is an interesting trail, pertinent to the discussion. So he sets a reproducer in action, photographs the whole trail out, and passes it to his friend for insertion in his own memex, there to be linked into the more general trail.

### Pushing the Limits

Wholly new forms of encyclopedias will appear, ready-made with a mesh of associative trails running through them, ready to be dropped into the memex and there amplified. The lawyer has at his touch the associated opinions and decisions of his whole experience and of the experience of friends and authorities. The patent attorney has on call the millions of issued patents, with familiar trails to every point of his client's interest. The physician, puzzled by a patient's reactions, strikes the trail established in studying an earlier similar case, and runs rapidly through analogous case histories, with side references to the classics for the pertinent anatomy and histology. The chemist, struggling with the synthesis of an organic compound, has all the chemical literature before him in his laboratory, with trails following the analogies of compounds, the side trails to their physical and chemical behavior.

The historian, with a vast chronological account of a people, parallels it with a skip trail which stops only on the salient items, and can follow at any time contemporary trails which lead him all over civilization at a particular epoch. There is a new profession of trail blazers, those who find delight in the task of establishing useful trails through the enormous mass of the common record. The inheritance from the master becomes not only his additions to the world's record, but for his disciples the entire scaffolding by which they were erected.

Thus science may implement the ways in which man produces, stores, and consults the record of the race. It might be striking to outline the instrumentalities of the future more spectacularly, rather than to stick closely to methods and elements now known and undergoing rapid development, as has been done here. Technical difficulties of all sorts have been ignored, certainly, but also ignored are means as yet unknown which may come any day to accelerate technical progress as violently as did the advent of the thermionic tube. In order that the picture may not be too commonplace, by reason of sticking to present-day patterns, it may be well to mention one such possibility, not to prophesy but merely to suggest, for prophecy based on extension of the known has substance, while prophecy founded on the unknown is only a doubly evolved guess.

All our steps in creating or absorbing material of the record proceed through one of the senses—the tactile when we touch keys, the oral when we speak or listen, the visual when we read. Is it not possible that some day the path may be established more directly?

We know that when the eye sees, all the consequent information is transmitted to the brain by means of electrical vibrations in the channel of the optic nerve. This is an exact analogy with the electrical vibrations which occur in the cable of the television set: they convey the picture from the photocells which see it to the radio transmitter from which it is broadcast. We know further that if we can approach that cable with the proper instruments, we do not need to touch it; we can pick up those vibrations by electrical induction and thus discover and reproduce the scene which is being transmitted, just as a telephone wire may be tapped for its message.

The impulses which flow in the arm nerves of a typist convey to her fingers the translated information which reaches her eye or ear, in order that the fingers

may be caused to strike the proper keys. Might not these currents be intercepted, either in the original form in which information is conveyed to the brain, or in the marvelously metamorphosed form in which they then proceed to the hand?

By bone conduction we already introduce sounds into the nerve channels of the deaf in order that they may hear. Is it not possible that we may learn to introduce them without the present cumbersomeness of first transforming electrical vibrations to mechanical ones, which the human mechanism promptly transforms back to the electrical form? With a couple of electrodes on the skull the encephalograph now produces pen-and-ink traces which bear some relation to the electrical phenomena going on in the brain itself. True, the record is unintelligible, except as it points out certain gross misfunctioning of the cerebral mechanism; but who would now place bounds on where such a thing may lead?

In the outside world, all forms of intelligence, whether of sound or sight, have been reduced to the form of varying currents in an electric circuit in order that they may be transmitted. Inside the human frame exactly the same sort of process occurs. Must we always transform to mechanical movements in order to proceed from one electrical phenomenon to another? It is a suggestive thought, but it hardly warrants prediction without losing touch with reality and immediateness.

Presumably man's spirit should be elevated if he can better review his shady past and analyze more completely and objectively his present problems. He has built a civilization so complex that he needs to mechanize his records more fully if he is to push his experiment to its logical conclusion and not merely become bogged down part way there by overtaxing his limited memory. His excursions may be more enjoyable if he can reacquire the privilege of forgetting the manifold things he does not need to have immediately at hand, with some assurance that he can find them again if they prove important.

The applications of science have built man a well-supplied house, and are teaching him to live healthily therein. They have enabled him to throw masses of people against one another with cruel weapons. They may yet allow him truly to encompass the great record and to grow in the wisdom of race experience. He may perish in conflict before he learns to wield that record for his true good. Yet, in the application of science to the needs and desires of man, It would seem to be a singularly unfortunate stage at which to terminate the process, or to lose hope as to the outcome.

## About the Author

Vannevar Bush was a pioneer in computer design who also distinguished himself as an engineer, an administrator, and a government official. He became president of the Carnegie Institute in Washington, D. C., in 1939, and was chairman of the National Advisory Committee for Aeronautics from 1939 to 1941. In 1941, President Roosevelt appointed Bush the first director of the Office of Scientific Research and Development, an agency to coordinate federally funded defense research. In this capacity, he directed the activities of some 6000 leading American scientists in the application of science to warfare.

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# Classroom Without Walls

Marshall McLuhan

Explorations, #7, May, 1957.

It's natural today to speak
of "audio and visual aids" to teaching,
for we still think of the book as norm,
of other media as incidental.
We also think of the new media
—press, radio, movies, TV—
as MASS MEDIA
& think of the book
as an individualistic form.

Individualistic because it
isolated the reader in silence &
helped create the Western "I."
Yet it was the first product of
mass production.

With it everybody could have
the same books.
It was impossible
in medieval times for
different students, different institutions,
to have copies of the same book.
Manuscripts, commentaries, were dictated.
Students memorized.

Instruction was almost entirely oral,
done in groups.
Solitary study was reserved for
the advanced scholar.
The first printed books were
"visual aids" to oral instruction.

Before the printing press,
the young learned by
listening, watching, doing.
So, until recently, our own
rural children learned the
language & skills of their elders.
Learning took place
outside the classroom.
Only those aiming at professional careers
went to school at all.

Today in our cities,
most learning occurs outside the classroom.
The sheer quantity of information conveyed by
press-mags-film-TV-radio
far exceeds
the quantity of information conveyed by
school instruction & texts.

This challenge has destroyed
the monopoly of the book as a teaching aid
& cracked the very walls of the classroom,
so suddenly,
we're confused, baffled.

In this violently upsetting social situation,
many teachers naturally view
the offerings of the new media
as entertainment,
rather than education.
But this view carries
no conviction to the student.
Find a classic
which wasn't first regarded
as light entertainment.
Nearly all vernacular works
were so regarded until the 19th century.

Many movies are obviously handled
with a degree of insight & maturity
at least equal to the level permitted
in today's textbooks.
Olivier's Henry V & Richard III
assemble a wealth of
scholarly & artistic skill
which reveal Shakespeare at a very high level,
yet in a way easy
for the young to enjoy.

The movie is to dramatic representation
what the book was to the manuscript.
It makes available
to many & at many times & places
what otherwise would be restricted
to a few at few times & places.
The movie, like the book,
is a ditto device.
TV shows to 50,000,000 simultaneously.
Some feel that the value
of experiencing a book
is diminished by being extended
to many minds.
This notion is always implicit
in the phrases "mass media," "mass entertainment" —
useless phrases obscuring the fact THAT
English itself
is a mass medium.
Today we're beginning to realize

that the new media aren't just
mechanical gimmicks
for creating worlds of illusion,
but new languages
with new & unique powers of expression.
Historically, the resources of English
have been shaped & expressed in
constantly new & changing ways.
The printing press changed,
not only the quantity of writing,
but the character of language
& the relations between author & public.
Radio, film, TV pushed
written English towards
the spontaneous shifts & freedom of
the spoken idiom.
They aided us in the recovery
of intense awareness of
facial language & bodily gesture.
If these "mass media"
should serve only
to weaken or corrupt
previously achieved levels of
verbal & pictorial culture,
it won't be because
there's anything inherently wrong with them.
It will be because we've failed
to master them as new languages in time
to assimilate then to
our total cultural heritage.
These new developments,
under quiet analytic survey,
point to a basic strategy of culture
for the classroom.
When the printed book first appeared,
it threatened
the oral procedures of teaching, and
created
the classroom as we now know it.
Instead of making
his own text, his own dictionary, his own grammar,
the student started out with these tools.
He could study, not one,
but several languages.
Today these new media
threaten, instead of merely reinforce,
the procedures of this traditional classroom.
It's customary to answer this threat
with denunciations of the unfortunate character & effect
of movies & TV,
just as the comicbook
was feared & scorned & rejected
from the classroom.
Its good and bad features
in form & content,
when carefully set beside
other kinds of art & narrative,
could have become a major
asset to the teacher.

Where student interest is already
intensely focused
is the natural point
at which to be
in the elucidation of
other problems & interests.
The educational task
is not only
to provide
basic tools
of perception,
but to develop
judgment & discrimination
with ordinary social experience.
Few students ever acquire skill
in analysis of newspapers.
Fewer have any ability to discuss
a movie intelligently.
To be articulate & discriminating
about ordinary affairs & information
is the mark of an educated man.
It's misleading to suppose
    there's any difference between
    education & entertainment.
This distinction merely relieves people
    of the responsibility of
    looking into the matter.
It's like setting up a distinction between
    didactic & lyric poetry
    on the ground that one
    teaches, the other pleases.
However, it's always been true
    that whatever pleases
    teaches more effectively.

# To Lead or to Follow: The Role and Influence of Research on Technology

SAUL ROCKMAN
PRESIDENT, ROCKMAN *ET AL.*

*We have expected a great deal of our schools and our teachers and have often been disappointed. The answer is not to lower our educational expectations, however, but to state them clearly so that the conditions necessary to their attainment also become clear.*
John Goodlad

## INTRODUCTION

The issue is an old one: What have we learned from research about the application of technology to teaching and learning? Not surprisingly, the answers are still the same. Now, we have to decide what we are going to do about these answers.

Research and research organizations provide documentation about what can and cannot be done. They serve as mediators in the sense that they can define, describe, and give a basis for decision making about educational technologies. Nevertheless, research is hard to disseminate; research is hard to compare; and gathering research data is often an excuse to do nothing. We have learned a lot from research, but there's a large gap between what we know is best practice and what we find to be ordinary practice in schools.

Fundamentally, we researchers have done a poor job of answering the policy questions asked by decision makers. Now that we are finally asking better questions (and doing better studies), we need to help the decision makers understand both the questions and the answers. While it still may be very important to learn whether we can teach significant materials, such as mathematics, using technology in ways that show up on standardized tests, we have to look beyond tests scores.

Below, I identify several problems surrounding research on technology in education, and specify some of the new directions that such research is taking. I also suggest how business is going forward with ideas that arise from research and address equity issues that emerge from increasing access to and implementation of technology in instruction. Finally, I conclude with notes on some of the policy issues focused on technology and research, and some concerns that policymakers must address as they deliberate the future directions of education.

## RESEARCH ISSUES

In reviewing the research on the effects technology has had over the past decade, I am struck by two somewhat contradictory conclusions: First, we have a collection of research indicating that students learn important knowledge and useful skills using computers. Krendl and Lieberman (1988), Roblyer and others (1988), the Office of Technology Assessment (U.S. Congress 1988, 1989), and others have compiled a comprehensive listing of research studies about this subject and have arrived at conclusions that certainly make sense to those of us in the field. Second, some of the same people who have been accumulating and reviewing the research also note that much of it is inadequate, inappropriate, and generally misleading. These facts lead me to ask two questions: Why do we continue to study the specific effects of technology?

And why is the quality of existing research typically poor?

## Why Do We Continue to Ask the Same Research Questions?

Almost 25 years ago, Chu and Schramm (1967) summarized the research on instructional television, stating:

> It has become clear that there is no longer any reason to raise the question of whether instructional television can serve as an efficient tool of learning. This is not to say that it always does, but the evidence is now overwhelming that it can, and, under favorable circumstances, does. The evidence now comes from many countries, from studies of all age levels from preschool to adults, and from a great variety of subject matter and learning objectives. The questions worth asking are no longer whether students can learn from it, but rather, (1) Does the situation call for it? and (2) How, in the given situation, can it be used effectively?

Twenty years later, Cambre (1987) made a similar statement in support of school television and its effect on learning:

> It has been established, unequivocally and irrevocably, that a well-designed and produced television program can and does teach. This is especially verifiable when the potentials of the medium are exploited and content visualization is maximized. It is most especially true in the hands of a skilled teacher.

While research on computers in the schools has not had as long a history of sustained study, Roblyer, Castine, and King (1988) report equivalent results for computers. In a series of statements they note:

> Computer applications seem to be potentially effective with students at all grade levels. . . . In each of the four content areas in which the research was summarized, CBE [computer-based education] was found to be more effective overall than the methods to which it was compared.
>
> . . All levels of skills in reading and mathematics should be expected to profit from computer-based methods. . . . Computer applications can be about equally effective with low-achieving and regular students.

Why have we been asking the same questions and coming up with the same answers for the past 25 years? I believe that the problem with computers, and in fact all electrical equipment, is that they must be plugged into the wall and about almost anything that gets plugged into a wall, people will repeatedly ask, "Does it work?" A stove heating a pot of water demonstrates that it works. In education, "Does it work?" usually means does it facilitate instruction and improve learning—not a simple task. Interestingly, we don't ask the same question about instructional materials that don't get plugged in. We may criticize textbooks, but rarely do we question their efficacy.

I have offered this view several times, and thought it flippant, a little cynical, and somewhat satisfying. But I really didn't understand the deeper meaning of "plugging it into the wall," until I read an extended quote from a book about electricity (Nye 1991).

> Every new technology is a social construction and the terms of its adoption are culturally determined. . . . Most people are not inventors, engineers, or utility employees, and for them a device is only real once they begin to incorporate it into everyday experience. For them, a new technology is at first a mysterious novelty. There was never a time when ordinary Americans understood electricity in purely functional terms; they have always responded to it with a touch of wonder and ascribed to it symbolic dimensions. . . . From the beginning, Americans have imbued electricity with meanings ranging from the grandiose visions of utopian novels to the metaphors of popular speech, in which people could get their wires crossed, suffer short circuits, and recharge their batteries. The electrification of America is thus far more than the study of inventions and corporations; it involves a popular absorption in the potentialities for personal and social transformation. As America electrified, in the imagination, it became electrifying.

Thus, we should not be surprised when people respond to the magic of television (You turn it on, and there it is!), to the awesome power of the computer (How did it do that so fast, and yet get my credit card bill wrong?), to the mind-bending possibilities of virtual reality. It may be the magic of how technology works that leads policymakers and researchers to continually return to the question of its value as an instructional tool. I propose that we begin to ask a new, but related question: How can we make technology work the way we want it to as an instructional tool?

## Why Is the Quality of Existing Research Typically Poor?

We have numerous articles showing that a good portion of the research studies on the effects of technology on achievement is trivial, poorly conducted, and lacks validity (Clark 1983, 1989; Rockman 1990). Moreover, many studies do not support the belief that computers, or other technologies, have a positive effect on learning. We are left with the conclusion that

either the computer doesn't make any difference in schools, or what we do with the computer doesn't make any difference. Both may be right. I see three main reasons for these conclusions:

(1) When we do research, especially when we try to work in the classroom setting, we often don't gather data on the issues that are actually influenced by the presence and use of technology. For instance, we put five computers in a room with simple mathematics software and dramatically change the teaching environment and the teaching patterns in that classroom, but then only ask whether the students' math scores have improved. We don't look at the changes in teacher behaviors and teaching even though it is those elements of instruction, not direct student learning on some small aspect of the total curriculum, that we may have influenced significantly.

For example, educators at the model technology schools in California have reported that, after a year or so of access to technology, administrative work decreased (e.g, record keeping became easier) thus giving them more time to spend with students; they felt that they could teach more effectively; and they expended more effort in planning (Stecher 1989). Regardless of what happened with the students, the availability of computers and other technologies had a significant effect on teachers' attitudes and behavior.

(2) We often conduct studies on minor implementation of technologies and then wonder why we don't see much improvement. For instance, after two weeks of teaching computer programming to 5th graders for 35 minutes a day, many researchers expect dramatic changes in their problem-solving abilities. Or we expect a game-like, mathematics drill-and-practice program used occasionally over a month to contribute to achievement score gains. These hypotheses assume obvious connections between a computer and the outcome measures, and ignore entirely the context of the school and the relative importance of these tasks. Such research on technology in education abounds, often because we overestimate the power of the technology and underestimate the contribution of the instruction.

(3) Another problem with current research is a lack of clear definition of the treatment. Not only are some treatments trivial, we don't always even know what they were when we read the research reports. As Polin (1991) observed, many studies look at the effect of computer equipment on achievement when only the media differed (for example, writing on a computer versus writing with paper and pencil). Either the presence or absence of the technology or some critical feature of the computer is believed responsible for the effects. Yet the actual instruction for using the technology is neither defined nor varied and nowhere is the writing instruction defined. We don't know what happened, just that some students used the computer and some did not. Clark (1983) noted that the instructional methods, not the medium, produce the differences in learning outcomes. The technology serves as a conduit for instructional materials and, he believes, when properly studied, the medium would be shown not to contribute to the outcome.

## New Research and Perspectives on Technology

We're beginning to change the nature of research on technology in schools. Many of us are no longer making comparisons between instruction with and without the technology, or asking straight line questions such as, "Can we teach subject X with technology Y?" We are beginning to see and study technology as something that is intended to extend instruction or augment the capabilities of the teachers and students. It can be a tool to get something done or a colleague to work along side of us. Our perspectives, like our technologies, are changing (Kozma 1991).

For the past several years, we, the technology advocates, have been promoting technology's ability to be integrated into the existing curriculum. I am beginning to feel that there are significant fallacies with this approach. A computer or a television set is often used to deliver the same instruction that teachers already provide, therefore, it does not add substantially to instructional content. Any gains may simply be a result of doing something twice rather than doing something better.

For instance, when Slavin (1991) looked at 21 studies of IBM's *Writing to Read* (WTR) program in kindergartens and 1st grades, he found that early achievement gains over two years were wiped out within a year. *Writing to Read* is costly, and the program is used to supplement the school's ongoing reading program with an hour a day of computer and writing activities. These costs can only be justified if *Writing to Read* provides significant and lasting effects on student achievement. Slavin identified alternate programs available through the National Diffusion Network (NDN) that have proven to be more effective in accomplishing the same goals and for a small fraction of the cost.

Several other researchers have examined the literature on *WTR*, and all have been critical of the program and its effects. Freyd and Lytle (1990) criticized the underlying instructional basis of the program. Krendl and Williams (1991) saw poor ex-

perimental design in the *WTR* evaluations and concluded that there was little evidence that *WTR* was any more effective than any other early writing process model.

We may do a lot of things with computers that appear to be exciting to students and motivate them to show up to class everyday, but if we don't change what we teach and we teach with technology I don't think it is wise to expect more than incremental improvements. I would rather see us use our time and energy to change the curriculum and change the way the curriculum is delivered with technology.

## New Research

Some of the current research differs dramatically from studies that ask if computers make a difference. These explore how and under what circumstances computers and other technologies can make changes in the classroom and improve instruction.

Researchers are developing more complex and comprehensive technology-based systems to enhance and extend what we are currently doing in schools. Newman (1990) describes a school computer network that can change the organization arrangements within a school, modify the instructional patterns, and influence social relationships among students. In his work with Earth Lab at an inner city school, the entire school environment, not just the technology, becomes part of the research focus.

Zellermayer, Salomon, and others (1991) developed a writing improvement tool that provides questions and writing suggestions to students as they use a computer to create essays. The research indicates not that the word-processing function improved writing, but rather that computer software that augments what students can already accomplish, by presenting writing guides and continuous higher level cognitive help, can make substantial improvements that are sustained over time and across technologies. It is not the tool/technology but the augmentation to instruction that makes the difference.

Salomon and others (1991) continued that line of argument by noting that we would not expect the introduction of a technology such as word processing to do more than make editing easier and provide the ability to correct spelling and grammar. There is no instruction inherent in a word processor. It does not substantially or consistently improve writing. However, when the technology or a teacher provides direct intervention or prompts structural revision, students are able to revise more intelligently and produce more rewarding and effective work.

In another study of computers in the classroom, Salomon (1990) recognized the need to incorporate technology in a social and instructional context so that it was not just technology, but a school ecology, that he studied. To make effective use of the computer under real classroom conditions, the researcher had to change most aspects of classroom teaching and learning "from a didactic mode of instruction to exploratory activities; from individual learning to cooperative learning teams; from passively rehearsing the Constitutional clauses to rewriting them; from being tested to formulating speeches during the "Convention;" and from acquiring computer literacy in a sterile "computer literacy" class to using the computer as a practical daily tool."

The Cognition and Technology Group at Vanderbilt University (1990) has taken commercial videodiscs (mainly feature films, such as Young Sherlock Holmes) and repurposed them to create meaningful environments for students to actively experience and explore certain concepts. The videodisc programs help students identify and focus on authentic tasks, as they help the protagonists accomplish goals or solve a problem posed in the video. The videodisc provides a rich context and cohesive information, which enable students to: (a) identify and define problems; (b) specify reasons for problem solution; (c) generate, under minimal teacher guidance, strategies for solving the identified problems; and (d) observe quickly the result of their attempted solution. The problems demand sustained thinking, often in groups, and encourage students to integrate skills and knowledge that, in traditional school curricula, remain disconnected. The approach works well with at-risk students because the stimulus materials do not presuppose extensive background knowledge. This instructional approach seems to be consistent with what the business and industry groups are asking of our students—that they be thinkers and problem solvers, be adaptable, and be able to work together to solve complex problems.

The studies I have just described—as well as the work of Scardamalia, Pea, and other researchers—take a very different approach to curriculum needs and offer students active, creative, meaningful, and diverse learning experiences. These studies can be contrasted with those that ask if the introduction of computers will increase test scores and those that explore the direct influence of computers without consideration of the context of instruction.

Becker (1991) stated in *The Computing Teacher* that the largest portion of instructional software in use today remains focused on recall of facts and algorithms rather than providing a learning environment for motivating higher-order thinking, problem solving, and deep understanding. Very little software

provides sophisticated assessment of student comprehension and truly individualized feedback to the level of sophistication of even a mediocre teacher. Moreover, most occasions on which students use 'tool-oriented' applications such as database, spreadsheet, and word-processing programs occur in computer education classes—not as part of instruction in mathematics, science, social studies, or English.

According to Sheingold and Hadley (1990), even the more sophisticated and experienced teachers with greater access to computers did not often live up to the most advanced notions of what and how technology should be used in schools. Nevertheless, these teachers did exhibit creative and far-ranging applications of technology for a variety of educational problems.

### A New Focus: Educational Outcomes vs. Technological Inputs

Some of the best current research is about a different set of issues. It looks at settings in which technology is being used, and supports what we are learning about instructional strategies and school change. Such research is exploring (in the context of technology implementation) many of the elements being explored by those interested in school restructuring: changes in the way people organize themselves for teaching and learning; making students more responsible for their own learning; focusing on higher-order skills and thinking; providing meaning to the sterile curriculum; and making active learning possible.

In the past, we have focused on studying the "inputs" to the classroom, incorporating technology for diverse reasons while being unsure of the potential outcome. Now we are looking at research on the educational outcomes such as learning, capabilities, and social relationships and seeing how we can use technology to help us improve these outcomes. Technology research is no longer being done in isolation from the context of education. Researchers are now moving beyond technology and focusing on instructional strategies that support student learning, including cooperative learning, collaborative learning, cross-age tutoring, active learning, project-based instruction, and so on.

In the early paradigm of school technology research, technology was the focus—we asked if technology made a difference. After years of research on instructional materials, the strong evidence points to the fact that implementation is what is most important (Elmore and McLaughlin 1988, McLaughlin 1990). What a teacher does with technology is more important than what the technology is. Unfortunately, as Becker points out (Becker 1991), we did not (and for the most part still do not) implement technology effectively.

## BUSINESS APPROACHES THE PROBLEM

While educational researchers are working toward more sound applications of technology to help students learn to communicate and solve problems, corporate researchers are designing more sophisticated systems to meet businesses' educational needs. Performance support systems (Gery 1989) using contemporary technology are emerging in corporations for on-the-job training purposes. These systems are collections of available resources (often computer-based materials) including information, software productivity tools, reference materials, guidance, and coaching aimed at improving learning. These systems can produce rapid proficiency with simulations and guided practice on exercises that take into account the job context.

These systems can be a model for education and are, in some way, being indirectly developed by some educational technology researchers. Technology-based performance support systems involve learning and doing and reference, all facilitated through a desktop computer. Consider a new employee who needs to learn what his job is, how to do it, and who to contact when help is needed. Answers to many routine questions are available on disk. These include information about what the particular job title is, the employee's role, and information about his colleagues. The materials tell the employee most of what he needs to know to go right to work.

This idea is presently being used by several university libraries, mainly because the high turnover rate of student workers places many demands on permanent staff. When employees needs help doing the job, they turn first to online help and then to just-in-time training. Online help tells where the employees are and where they can go; it provides orientation, but it doesn't help do the job. Online help is becoming fairly common on complex multimedia systems as well as on productivity software.

Just-in-time training tells how to do something at the moment employees need to learn it so that they can immediately go back and apply the learning. When employees have trouble performing certain tasks, the just-in-time training might provide a simu-



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lation to teach the concepts, some step-by-step examples for practice, and opportunities to apply the new knowledge when ready.

When the need to learn more arises, employees might need some reference assistance. The performance support system provides online referrals to people or materials with information, collegial support, and new opportunities for personal growth. Employees can be in touch with a network of colleagues and experts who can inform and direct their work.

Whether a system of this kind is practical in the near future for education depends greatly on the kinds of curriculum we want to provide our students. Performance support systems are certainly expensive. Corporations, while they find them powerful, are moving slowly to develop them. Much of what we currently do in school focuses on memorization and management rather than practical performance. But as new curricular ideas become more prevalent, technologies can rise to the challenge of providing meaningful and motivating instruction that does improve performance in context.

## TECHNOLOGY, AT-RISK STUDENTS, AND EQUITY

Because of their high concentration of at-risk students, urban schools are most likely to dumb-down curricula and stifle teaching in the name of higher test scores. Carol Ascher (1990) maintains, "Standardized tests influence the fate of students, teachers, and curriculum far more in schools serving low-income and minority students than in the suburban schools." Ascher notes that schools are caught in a bind as outside pressures to raise student achievement levels force them to rely heavily on standardized achievement tests on which minority and low-income students traditionally don't do well. Ascher reports that urban districts establish school goals based on standardized test scores and their principals are more likely to look at these scores for signs of growth and change than principals in middle-class schools. As a result, urban schools simplify their curricula and force teachers to teach to standardized tests more than their counterparts in rural or suburban schools. Thus, community and parental demands, based on standardized test scores, are limiting what can be taught in these schools.

Knapp and Shields (1990) substantiate the constraining instructional practices used with poor and minority children and distinguish them from the more ambitious "best practices" found in wealthier areas. Drill and practice is the most prevalent kind of instruction for many children. In many minds, drill and practice is synonymous with computers.

Many people believe that students at risk of school failure, often racial minorities, use computers for isolated skill development and remediation. Students work on drill-and-practice programs, such as computation and the mechanics of written language, that are mainly imposed to raise test scores. In suburban schools, where test scores are higher, students use computers for more meaningful tasks in problem solving and critical thinking. Rather than the teacher or the computer directing all aspects of their classroom instruction, these students have more responsibility for their own learning, on the computer and off.

While there is evidence that these two distinctively different approaches to teaching and learning are more widely practiced than one might wish, the computer is neither the cause nor the sole culprit. Knapp and Shields (1990) conclude that less-than-best-practices of all kinds are more prevalent for poor and minority children. These strategies are implemented without computers or other technologies and reflect a broader concept of what is appropriate instruction for particular groups of students. It is true that students in wealthier school districts work on computer-based, problem-solving materials that encourage different behaviors than the skills software used by inner city schools for drill and practice. However, it is the way these programs are used rather than the programs themselves that make the difference. Many of the more inventive and creative pieces of software that call for student responsibility and autonomy are trivial pieces of instruction in themselves. They deal in small units and with supplemental aspects of the curriculum. Teachers in suburban and wealthier schools are more likely to allow their students to explore and take responsibility for more of their computer use than are teachers in the inner city. This may mean regrouping students and moving around the room, even noisy classrooms. Urban schools are more likely to strive for quiet classrooms and obedient students. It is the implementation strategy for computer use in the more elite schools that makes it worthwhile and differentiates it from computer use in urban, inner city schools. Only when urban educators feel free to promote independent, active learning and personal responsibility as much as the memorization of discrete facts and improved achievement scores will we see best practices of computer use in those schools. Educators should ignore calls for technology equity and start exploring ways to achieve equity using technology. That is both a more difficult and a more important challenge.

## ASSESSMENT

The use of computers in assessment and testing may be the gun that keeps shooting us in the foot or in the knee or in the stomach, depending on how seriously wounded you believe we are. Computers have made mass testing and test scoring convenient, economical, and widely available. But that doesn't mean it's made such assessment practices good or valuable for education. Without the computer, we would rely more on teacher-made tests for meaningful assessment, do much less testing (because the effort and turn-around time for scoring would be increased), and probably do different kinds of testing.

We have been very sophisticated in developing mathematical models of assessment, sampling procedures, and even using the computer to do adaptive testing in ways that significantly lessen the burden on students. We have done research in latent trait analyses and item-response theory. Yet, as we begin to understand more about cognitive theory as applied in our schools and more about the social and cultural context in which learning is taking place, perhaps we are applying late 20th century mathematics and technology-driven assessment tools to 19th century schools. And worse, schools may not be structured to accommodate such innovations. In fact, by providing material for an ill-adaptive structure, we might be inhibiting schools from moving into the 21st century and keeping them from adopting an information-age curriculum.

### New Assessment Approaches

There is much work on new assessment approaches, some of which use the computer and other technologies. The Office of Technology Assessment is currently preparing a major report on testing and assessment, which will include a section on technology's role in these practices. The University of Pittsburgh (LRDC) and the National Center for Education and the Economy are collaborating on the development of alternative assessments for thinking skills. Educational Testing Service (ETS) is doing videodisc training and assessment for nursing, and computer-based simulation for assessing architecture candidates' abilities to solve design problems but it is not reportedly working on a substitute for National Assessment of Educational Progress (NAEP) or their standardized tests using technology. There are now a variety of computerized versions of standardized tests, but few innovative assessments using technology.

One innovation facilitated by technology is the portfolio assessment. A Maine elementary school is trying a portfolio assessment system that stores a student's work on disk. Students select their best work for the week, as do the teachers, and then store it electronically. The school expects that by the time students finish high school they will walk away with a CD-ROM of their accumulated accomplishments. This move, from the manila or construction paper folder to electronics, means that it is now possible to conveniently store and accumulate information about students' progress. Electronic portfolios even make it possible to accumulate videotape presentations that show changes in behavior and performance, student-made videos, collections of electronic music, and other artwork.

Vermont and several other states are seriously exploring portfolio assessments as a means of reducing reliance on standardized tests for assessing individuals, schools, and school systems. Portfolios tend to reflect more of what we are coming to want students to learn. They also make students demonstrate more behaviors that are applicable in the workforce.

Technology can also play a role in managing the portfolios. New developments in software, such as the TextBrowser (Kurland 1991), augment teachers' capabilities for assessing student writing by collecting and organizing specified characteristics of student writing samples, analyzing them according to a set of criteria, helping the teacher add notes and thoughts on issues, and managing, aggregating, and reducing the collection of information over time.

Portfolio assessments, whether they use the computer or not, necessitate a series of changes in the classroom, in the school administration, and in the public's attitude. First, such assessment requires substantial staff development to help teachers learn new ways of interpreting student ideas and accomplishments. As a corollary, the tasks in portfolios may change the teacher's instructional approach by giving more responsibility for learning to students. Such assessment lends itself to larger, more complex activities rather than small chunks of information for memorization. Second, portfolio assessments also need a support structure that encourages a different approach to establishing criteria because what students do may not closely resemble what they have been graded on in the past. It may mean reorganizing the school day to provide teachers' time to develop, monitor, and

assess the portfolios. And third, the community must understand and be willing to accept this approach to student assessment. Parents will have an easier time because portfolios tend to include many products, tangible proof of accomplishment that parents can review and discuss with their children.

Computers and videos can be used in other ways as assessment tools. Collins and Hawkins (1991) propose a series of complex activities and performances that can demonstrate successful learning in science. Students can make video presentations to explain complex data and show that they can follow directions and work cooperatively in joint problem-solving tasks. They can use the computer to formulate and demonstrate relationships between variables or to design an experiment or product that proves their knowledge of a concept.

While these are mostly exploratory efforts at present, researchers are working to develop contextually relevant uses of technology for assessment. The power of technology can be brought to bear on the collection and management of the large amounts of information required in authentic assessments, and on the nature of the problems assigned in these assessments. It can also be used in student performances and products to illustrate accomplishments and competencies.

There are many factors that hinder the use of performance tests. These assessments can be difficult and costly to administer and grade objectively and are surrounded by cultural biases. But it is clear that educators need to look for more powerful and appropriate ways to measure achievement, particularly for students currently being subjected to test-driven curricula. We need to start doing assessments that focus on what students can do or are attempting to do rather than on what students don't know or can't do. We need positive approaches to evaluation with realistic standards goals. Technology can help us develop these elements of assessment.

## DEMONSTRATION VERSUS RESEARCH

When we begin to look around the nation, we see mostly demonstration projects such as model technology schools, not research projects. We may embed research in these projects, but what we are really looking for are illustrations of exemplary practice. Unfortunately, we have rarely sustained the demonstrations long enough for technology innovations to take hold. Even rarer is the demonstration that allows for the full implementation of and benefit from an innovation. Commonly, policymakers and funders perceive innovative projects as an event, not a process; change is expected to occur shortly after funds are allocated and the equipment is installed. This is an unrealistic expectation.

For many of these projects, the fiscal resources are neither sufficient nor available for long enough periods of time for the technologies and their implementation to be determined to be successful and to be adopted or adapted by other schools. Additionally, it is hard to even know if schools can replicate successful models because, typically, funds provided for a school to be a demonstration site are much greater than those provided to a school interested in becoming an adoption site.

Hall (1991) points out the new reality that innovations and change agents are not enough to create change. Hall portrays a model for school change that involves the innovation (the change being sought), the interventions (the actions of policymakers and change facilitators), and the context of the user system (including classroom, school, school district, and perhaps the state). The change process is the application of the innovation and the intervention in the context of the user. What takes place in context is critical to success; administrators, teachers, students, parents, and the community are all part of the change process.

Hall notes that a great proportion of available funding goes to the development of innovations, and not to their implementation and dissemination. He suggests if a state or district sets up a demonstration site and obtains some positive and widely applicable results, it should recognize that an equal amount of time and money is needed to get it effectively adopted or adapted by other schools.

And even with the fiscal resources, transferring new ideas is not simple. Innovations in education produce radically different results in every classroom; individual classrooms are so different that no single solution is likely to work in two of them. Federal, state, and district policies that focus on implementation of technology or other innovations at the classroom level are doomed from the beginning because of the difficulty of generalizing innovations from site to site and producing sustained improvements in student achievement. Teachers shut the door and do what they want. According to E. Pauly (1991), policies applied at the classroom level are thoroughly reworked by the actions of teachers and students. Teachers take a policy statement and shape it in terms of what they already know and are already doing and then reframe it for their use.

## BEWARE OF THE TECHNOLOGY (RESEARCH) SOLUTION

Perelman (1989) has made a strong but misleading argument that technology can be thought of seriously as a replacement for labor-intensive teaching. He suggests that, as business has put money into technology-based instruction to create a capable workforce—or at least one competent to do well-specified tasks—so should education. The costs are in the hundreds of millions (or billions), but, as Perelman asks, what does that matter if you can attain productivity improvements? In business, these costs get passed along to the consumer. The taxpayers (and the President) are indicating that additional costs for education should not be passed along, at least for the time being. Resources to develop software in sufficient quantities to make a difference in education, to distribute and train people to use it, and to assess its effect upon education seem well beyond us at present.

Along the same line, Perelman argues for the investment of 1 percent of our education budget in research. While this is a desirable end, the implementation of what we already know not a search for new knowledge and understanding is needed in education. Certainly, as the National Academy of Education has suggested, a well-funded research agenda would be a worthwhile long-term investment, but we still haven't funded the Head Start programs that we know will make a difference over the next few years.

When considering Perelman's proposition on research funding we must wonder about the eventual return-on-investment of the 1 percent allocation if there is no money for adoption and implementation of the findings. For instance, class size and student achievement have long been highly visible policy issues influenced by emotions and large costs similar to the emotions and costs attached to technology as a means to significant achievement gains. Odden (1990) points out that, not only is the cost issue prohibitive (an estimated $250 million just to reduce class size by one student per class in California), but it is misleading. Only when class size reductions are coupled with other changes will achievement gains be found that come anywhere near the size required to justify large investments of new funds. Besides, many schools (especially poor, urban schools) need much more than just class size reductions or just technology. Becker suggests that getting "computers to make a difference in how students experience schooling will require teachers and administrators to modify their concepts of appropriate and inappropriate teaching behaviors, to reprioritize the value of different types of instructional content, and to change habits and assumptions that guide their classroom and school management strategies." We need to be reminded to beware of simple and simplistic solutions.

## SO NOW WHAT?

During this period of school change and restructuring there are some technology and research policy issues that require attention. These issues need to be folded into deliberations about the appropriate roles for technology and for research.

- We need to undertake research on the large state initiatives that have been undertaken over the past few years - dispassionate, independent research on major efforts to introduce technology and make substantive changes in education. Such projects as California's Model Technology Schools, Michigan's Classrooms of Tomorrow, Texas' new fiscal support of technology in schools, and efforts in Indiana, Arkansas, and elsewhere need to be examined, not for the simplistic outcome of increased test scores, but for the larger issues of school change and lasting influence on the education process. For instance, a study of the impact of more than $50 million in small technology grants in California showed that, for many of the school sites, it was the first time many schools and academic departments actively planned for the application of technology or the introduction of an innovation (Rockman, et al. 1987). Moreover, schools that did not receive funding started to implement their site-based plan for technology with their local funds. The availability of funds had a major influence on how schools operated, even though the money did not always directly influence test scores.
- We must consider the fact that, at the moment, technology in education may need restructuring more than restructuring needs technology. The nation is looking for dramatic change, which technology can be a part of. However, if the change efforts are not thought through, then technology could be part of a more systemic failure syndrome. The role of technology must not be defined by external demands for achievement gains using inappropriate instruments, but rather by local educators defining a proper place for technology in the context of their schools. But they, too, should be aware of and work toward the broad societal goals set for education.
- We need to understand that externally imposed policies regarding technology are likely to be met with some resistance. Because all school change is local it needs to be defined by the local institu-

tions; decisions and options should remain at the school level whenever possible. Slavin reports that the *Writing To Read* project was acquired from top-down policymakers, not educators, and imposed on individual schools. Lasting change needs the support of teachers, administrators, and the community.

- We are likely to need more education for educational decision makers. If technology is going to play a meaningful role, we must help decision makers understand that continuing to ask the same questions and expecting simple answers from existing measures is a barrier to change. If technology is going to be associated with significant change in schooling, then money for development of demonstration sites and acquisition of hardware must be matched—dollar for dollar—with staff development and support for implementation efforts.
- We must coordinate research and reform. Reforms are rarely based on research findings as research tends to follow, not lead the change process because the money follows the reforms and research follows the money (House 1991). The policies emerging from federal and state levels do not sufficiently take into account how schools operate. Policies get adapted and adopted, just like innovations.
- We need to think about the long term. At a time of budgetary constraints and real economic depression in some states, the business community is determined to make changes regardless of their long-term value for education. Their presumption and influence, with federal encouragement, is taking the leadership away from state and local education officials. The business community often focuses on productivity and short-term gains on easily measured outcomes. It is of no use to do inappropriate things better and faster with technology. We should do more useful things to produce a highly capable workforce, not only a highly skilled one. Our challenge is teaching people how to learn and motivating them to keep learning throughout their lives. We can no longer talk about a "better" educated workforce, we need a differently educated one.
- We must look at the potential value of technology in education. To the degree that technologies can be used to advance the educational goals we value, we should develop policies that encourage its application and use. For instance, the fact that technology encourages cooperative learning or independent learning or cross-disciplinary active learning makes it valuable to schools attempting to change their instructional practices. But technology must be used to help us reach our goals, it must not become a goal itself.
- We need to be realistic leaders. Leadership is important, but only if it provides a set of goals that can reasonably be attained and the resources to reach them. We may not find ourselves in that position during this cycle of school reform, regardless of our hopes. Monitoring and coercion are not the stuff of meaningful and sustained school change. Setting up models without the resources to introduce, support, and sustain adoptions by other schools is senseless. The question is not whether we can improve education, it is whether or not we have the dollars, the political will, and the stamina to change education in significant ways. It is not a matter of leadership, but of leadership that intelligently directs educators to do what they know they must do—and leadership that supports the needed changes with resolve and resources.

The educational technology community is seeing a lot of innovation, but not much real change. We can articulate the problems of schools, but we can't articulate solutions. Research is working on promising ideas to help make schools what we want them to be. I would rather that our goals be beyond our grasp than that they be limited because we have no vision.

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# Technology Integration and Teachers' Professional Development

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## INTRODUCTION

It is now well understood that the challenge of integrating technology into schools and classrooms is much more mental than it is technological. What's more, it is not fundamentally about helping people to operate machines. Rather, it is about helping people, primarily teachers, integrate these technologies into their teaching as tools of a profession that is being redefined through the incorporation process. When teachers effectively integrate technology into their classrooms, those classrooms change.

Although teachers are the designers in practice of this innovation, what teachers are able to do with technologies is either supported or limited by the circumstances in which they teach. These circumstances include the leadership, resources, policies, and goals throughout the school, district, state, and nation. Indeed, it is unlikely that widespread integration can take place unless it is tied to reform efforts (Sheingold 1991).

### Technologies on the Periphery

At all levels of our current system, we find technologies to be peripheral to teaching and learning. Many schools now own technologies, in particular computers and VCRs. Some also have multimedia systems, video cameras, and various forms of telecommunications. But these technologies are not generally integral to classroom-based curricular teaching (Becker 1990, U.S. Congress 1988). Often, they are the domain of technology specialists rather than classroom or subject-matter teachers. And, generally, because resources are limited, they are located in labs and not classrooms. Thus, teachers and students must devote considerable effort simply to gaining access to the technologies. More importantly, teachers who are now using technologies in schools have had to learn about, get help with, and create in practice their uses of technology because such instruction was not an integral part of their preservice education.

Admittedly, some colleges and universities offer technology in education courses to their students, some require an overview technology course for their teacher education students, and some offer a special degree program to prepare students to become technology specialists and coordinators. There are also programs for library media specialists in which students learn a great deal about technologies. But technologies do not pervade and infuse teacher education curricula. Students who are learning how to teach mathematics, science, and writing do not routinely encounter interactive technologies in their curriculum and methods classes. This is not surprising, because teacher educators have not themselves had instruction in technology integration or infused technology into their practice or taken time to think about how technology can inform and advance their field and its purposes.

The scope of the problem is large and disturbing. Like so many other problems in education, it raises questions about where and how to begin. How do we help teachers to teach in ways they were not taught, to create classrooms unlike the ones they studied in, and to develop confidence that they are doing the right thing for their students? And where are we going? What does integration mean? What do we want it to mean?

This paper focuses on practicing teachers, rather than on other people in school systems or preservice teachers, for several reasons. First, although other people in schools are important, teachers are at the center of any school-based innovation; what they learn how to do with technologies will define the impact of technologies in their classrooms and schools for many years. Second, to the extent that anything significant has already happened with technology in education, it has happened in schools and not in teacher education. Almost without exception, teacher education has not begun to address the integration of technologies in schools. In addition, although teacher education is very important, learning how to teach does not end with getting a degree or certificate. Many would argue it only begins there, that much of what teachers learn they learn on the job (Ball 1990). This has certainly been true with respect to technologies, because it is in schools that technological advances have been most readily applied. Therefore, a key to effective technological integration is helping schools become places where teachers' continued learning and professional development is expected and supported.

What do we mean by the integration of technologies into schools? There is no simple prescription or formula for the way such integration will or should look. Indeed, we expect to find several varieties of effective integration of technologies into schools and districts (Sheingold and Hadley 1991). Under any circumstances, however, two goals are central for the integration of technologies into teaching.

- First, that teachers can comfortably and flexibly use technologies (e.g., computers, multimedia, and telecommunications) to support and enhance student learning throughout the curriculum.
- Second, that teachers can comfortably and flexibly use technologies to enhance and support their own communication, productivity, and learning as professionals.

Sound simple? Most of the rest of this paper explores just how challenging these two goals are, what is needed to make them a reality, and why technology integration must be an integral part of systemic school reform.

## THE INTEGRATION OF TECHNOLOGIES INTO TEACHING

What is involved in integrating technology into teaching? How do we move technologies from the periphery of school activity into the very center of teaching and learning, in preservice education as well as schools? There are no well-studied models of teacher education and support at the preservice or inservice levels. Moreover, there are not yet mature, well-studied examples of technology integration in schools, districts, and teacher education programs that can provide end points for this discussion—that can tell us what fully integrated use looks like and how it functions. Fortunately, there has been some research over the last five years that, while limited and mostly still in progress, can help us understand what is involved for teachers in integrating technology into classroom practice. From this work we can derive implications for what is needed to support this process. The research comes from classroom and school-based examples of technology incorporation and use over several years (e.g., Collins, Hawkins, and Carver 1991; Dwyer, Ringstaff, and Sandholtz 1990), as well as from a recent national survey of teachers who are experienced at integrating computer technology into their teaching (Sheingold and Hadley 1990). These studies have focused on computers, but include, in some cases, multimedia technologies, local area networks, and video.

With good reason, most of the research has come from schools that are unusual; if for no other reason than that some kind of experiment in technology integration is happening in them. It is important that we remember that these schools are unusual when we try to generalize their actions to more typical schools. The studies included here have taken place in schools and classrooms that span a wide variety of communities, with respect to geographic location, socioeconomic status, and ethnic composition of the student body and local community. So, while they are advantaged with respect to technology-related support, many are not unusual in other respects.

### The Process

Integrating technology into teaching practice, from the perspective of teachers, is a complex process of professional development. Its components generally include: gaining increasing comfort and facility with hardware and software; finding software and ways of using it that are consistent with teaching goals; experimenting with alternative ways of using the technology with students; learning new ways of teaching by observing students using technologies; and noticing, being challenged by, and taking advantage of the new forms of classroom organization and management afforded by technology. All of these developments provide opportunities for teachers to reconsider and reshape their own classroom practices and pedagogy. And, under certain circumstances, the long-term effort to incorporate technologies challenges teachers to reconsider, reorganize, and learn more about the

subject matter they teach.

It is clear now that this process is not simple and linear. Teachers become confident that they know better how to incorporate the technology, only to discover that there is much more to be learned. They begin to feel comfortable with a classroom in which students are busily engaged in work with other students, and then revert back to greater control over the classroom through lecturing (Dwyer, Ringstaff, and Sandholtz 1990). There are continual "tugs" between a traditional vision of what school is supposed to look and feel like, what teachers have felt comfortable doing for many years, and the kinds of activities, experiences, and associated changes technology brings to classrooms.

What keeps this process going? There are three easily identifiable factors—student enthusiasm and motivation, teachers' own development, and various forms of support. Student enthusiasm and motivation are consistently powerful motivators for teachers. Under many different circumstances of computer use and integration, teachers continue to work at the integration and use of technologies because of what they see their students doing. They see students much more engaged in work, often working together on tasks that are increasingly complex and challenging. They see students doing work they (the teachers) may not have thought them capable of undertaking (Collins, Hawkins, and Carver 1991; Lampert 1988a; Sheingold and Hadley 1990).

Teachers' own professional development is a second factor that helps some teachers to continue their involvement with technology integration. For some, the effort involved in incorporating technology is repaid by their pride in developing new knowledge and skills (Herman, Heath, Valdes, and Brooks 1991; Sheingold and Hadley 1990). In some instances, teachers self-select into technology-related activities precisely because they want to learn new skills and have lost interest in doing things the old way (Cline and Mandinach, personal communication).

Support is another factor that helps teachers to stick with efforts to integrate technology. Support refers to the external resources and help that enable teachers to overcome the problems they encounter along the way and see that their effort is worth it. Support ranges from adequate amounts of technology to supportive leadership and colleagues to opportunities for professional development.

## Key Patterns

There is good reason to believe that there will be many different types of technology-integrated schools once schools have the requisite support and resources. Nonetheless, across a range of schools and studies on technology integration there appear to be some trends or patterns as far as what teachers do and how classrooms look. I present them here as a way of clarifying the kinds of transformations that may be expected under supportive circumstances. Let me caution here that this exercise is somewhat speculative, and derives as much from unpublished documents and conversations with researchers as it does from publications.

Patterns have been observed in what and how much software is used; classroom management and organization; types of technology-based classroom activities; the relation of technologies to instruction and curriculum; and relations among teachers.

### What and How Much Software is Used

In studies that have not prescribed particular software, findings indicate a trend from drill-and-practice software to tool-like applications (including word processors and databases) and more advanced technologies including desktop publishing and Hypercard (Dwyer et al. 1990, Sheingold and Hadley 1990). This trend may, however, be more an artifact of recent technological history than a necessary component of the integration process. A number of projects have begun by making, for example, multimedia and video production capabilities available to schools from the start. Without any initial introduction to more workbook-like software, teachers and students have begun their technology use through these more advanced systems (e.g., Collins, Hawkins, and Carver 1991; Herman, Heath, Valdes, and Brooks 1991; Spoehr 1991). Nonetheless, when working with these more advanced systems, teachers tend to use them at first in ways that are more familiar, and, only after considerable experience, take advantage of their unique features (Brunner 1991).

There is also a trend toward a wider variety of uses (Sheingold and Hadley 1990; Stearns, David, Hanson, Ringstaff, and Schneider 1991; U.S. Congress 1988) among computer-using teachers. As teachers become more knowledgeable, they try out and incorporate more types of software into their teaching. With experience, teachers appear to use computer-based technologies as flexible, multipurpose tools.

### Classroom Management and Organization

A consistent finding across many sites and studies is that technology-infused classrooms are organized in a more student-centered fashion (Collins 1991; Cumming 1988; Gearhart, Herman, Baker, Novak, and Whittaker 1991; Herman et al. 1991; Mandinach and Cline in press; L. Morris, personal communica-

tion; Sheingold and Hadley 1991). Students tend to be working individually or in small groups with the teacher attending to individuals and groups as needed. The teacher functions more as a coach or guide while the students engage in their technology-related tasks. This student-centered form of organization does not necessarily carry over to the times when the technology is not in use (Gearhart et al. 1991). However, as the time spent using the technology increases (Cline and Mandinach, personal communication), so does the time this sort of classroom organization is in place.

For most teachers this change in classroom organization represents a very major role change. Even some teachers who believed they were running student-centered classrooms before they started using computers are made to confront afresh what student-centered really means (Bank Street College 1991). Teachers not used to this form of classroom organization are initially uncomfortable. These teachers are used to being the center of attention, in control, delivering information and instructions to their students. During technology-related activities they feel much less in control. While some teachers easily adapt to this structure, and many embrace it over a period of time, some may never be completely comfortable with it.

Teachers who are enthusiastic about this shift from a teacher-centered to a more student-centered classroom enjoy seeing students so engaged in their work (Dwyer et al. 1990) and like being able to give students more individualized attention (Sheingold and Hadley 1990). There is some evidence that teachers may give more help to weaker students in computer-infused classrooms (Schofield, Evan-Rhodes, and Huber 1990). In one freshman college writing course, less able students received considerably more attention from teachers when the course was over a computer network than in a traditional classroom setting (Hartman et al. 1991). Other researchers report that teachers give more tailored help to students—interacting differently with more and less able students—and that female students, who would not normally ask a question or ask for help in the traditional classroom setting, do so freely during computer-based work (Cline and Mandinach, personal communication).

### Types of Technology-Based Classroom Activities

Technology-based activities in classrooms can mimic what happens with older technologies—books, pencils and paper, and chalkboards. Computers can be used as presentation and demonstration tools by a teacher in front of a class, or by individual students as electronic seatwork. But several studies document teachers' moves from more text-based, conventional uses of technology to more interactive and project-based uses (Dwyer et al. 1990, Sheingold and Hadley 1990). Tool-like uses of computers, word processors, spreadsheets, desktop publishing, and, increasingly, multimedia production tools are supporting an increasing emphasis on student involvement in more long-term, inquiry-oriented and product-making activities.

### Relation of Technologies to Instruction and the Curriculum

The long-term process of integrating technologies into teaching, learning, and the curriculum is highlighting the increasing relevance of technologies to classroom instruction (Polin 1990) and the need to modify classroom instruction as the potential of technology is discovered, tested, and shaped in the classroom environment (Cumming 1988; Dwyer et al. 1990; Lampert 1988a, 1988b; Wiske and House 1990). During the integration process, the technology moves from a highly peripheral status and use to the core of the curricular instruction, which is altered and reinterpreted through the use of the technology.

How do we know when technology is becoming part of the core of curricular instruction? We can imagine an advanced form of integration in which multiple technologies are used flexibly and in a matter-of-fact way to support instruction whenever teachers or students find it useful and appropriate—a time when technologies become a normal and everyday part of classroom life, and their use requires neither special effort (such as going to another room) nor special notice. There may not be any classrooms yet that have reached this stage, but there are classrooms where technologies are used for long-term student projects and major curriculum units. When technologies are used frequently to support students' curricular work (work that counts, that is graded or evaluated), then integration has begun (Polin 1990). However, as already indicated, these classrooms may look and function quite differently from traditional classrooms.

For teachers, the process of integrating technologies with instruction and pedagogy offers the opportunity to examine and revise instructional practices and beliefs. This is particularly evident when teachers use technologies to involve students actively in building their own knowledge and understanding, typically through complex, real-world tasks. Just how far this process goes, and how much and what kinds of changes are observed in teachers' practices is not consistent across sites and cases. Often, teachers must confront important issues about the nature of the

domain they are teaching, where authority for knowledge lies, and how curriculum is defined.

*The nature of the domain.* There are numerous examples of teachers' rethinking the domain that they teach in the process of integrating technologies into their classrooms. The following example was well-studied from the perspective of teachers' changing beliefs and practices.

What does it mean to know geometry? That question became central for a group of teachers who regularly used the Geometric Supposer (Schwartz, Yerushalmy, and Education Department Center 1985-87; Lampert 1988b) in their classrooms as part of a research project. The Supposer is a software tool that allows students to do their own geometrical inquiry and make their own inductions about geometric relations. This kind of learning poses problems for what most teachers believe geometry is—a logical and deductive progression of a predetermined set of definitions, axioms, and theorems. Teachers changed their views on this matter as a result of observing what their students were doing with this technology. They saw students deeply engaged in generating, discussing, discovering, and arguing about geometry, a subject that did not previously interest them. Students were actually doing geometry. But they were doing it inductively, not deductively, and in an order that they, not the textbook or teacher, determined. In the face of this compelling evidence of student learning and involvement, teachers came to view geometry as a web of important ideas and relationships rather than as a necessarily predetermined sequence of ideas. They came to value both induction and deduction as relevant to doing geometry.

*Authority for knowledge.* In most classrooms, students have no authority or responsibility for having or generating knowledge; it is their job to "get" it from teachers and textbooks. With technologies that enable students to conduct their own inquiry, however, this authority gradually becomes shared (Collins, Newman, and Bayer 1991; Lampert 1988b; Scardamalia and Bereiter 1991). Students in the geometry example generated their own conjectures about geometric relations, which then became legitimate topics for classroom discussion and consideration. This sharing of authority is not an easy step for teachers. But sharing authority is not the same as giving it up. In cases where teachers expect that they can simply leave the students and the technology to their own devices, the outcomes for students are often not productive (Bank Street College 1991; Newman and Torzs 1990; Rubin in press).

As students take on the kinds of technology-based learning that enables them to generate knowledge, teachers have a central role to play helping students make sense of what they have done (Newman and Torzs 1990; Rubin in press), and helping them to see how their investigation relates to larger and more general models, theories, and ideas. To do this effectively, teachers must learn how to involve students in discussions that help them analyze, assess, and draw conclusions. This requires a significant change in the kinds of conversations that typically take place between teachers and students in the classroom.

*How curriculum is defined.* Curriculum is generally defined as a sequence of topics or chapters to be covered over a semester or a year. Teachers are often challenged to regard curriculum differently once their students have access to interactive technologies. In the geometry example, teachers could not simultaneously have their students doing geometry with the Supposer and hold to a rigid view about how to sequence curriculum topics. What they did instead was to determine the central ideas in the curriculum, and make connections between these and student work over the course of the year. The sequential notion of the curriculum was thus significantly changed, but many of the important ideas were retained.

Teachers often find that when using technologies to support students' active involvement with learning tasks they cannot "cover" as much content as they are supposed to (Cumming 1988). While students may be working on tasks that expand their understanding of important ideas, teachers must decide whether to cover the whole curriculum or help students to more thoroughly understand a limited set of topics. This creates a dilemma for teachers in schools where amount covered is more important than students' understanding of the content.

### Relations Among Teachers

In many of the sites studied, technology-infused schools and classrooms have required or resulted in teachers' working together, often on common cross-curricular projects (Bank Street College 1991; Reese in press; Sandholtz, Ringstaff, and Dwyer 1991; Spoehr 1991). In one project, teachers integrating computer-based technology and systems thinking (and related software) into their classrooms have three release days per year to use for any project-related activity they choose. Most choose to spend these days with other teachers, either from their own or other participating schools, working on systems models (Cline and Mandinach, personal communication). In these schools, teachers spend more time interacting with each other about issues related to teaching than they had in the past.

Technology integration can also result in more supportive relationships among teachers, as teachers develop and share particular forms of technology-related expertise. In some schools and districts, teachers who have developed competence and confidence with technology act as mentors for other teachers, provide inservice courses and workshops at local schools, and make presentations at conferences. In some model school projects, these kinds of developments are encouraged and expected as a way to broaden the innovation.

## INTEGRATING TECHNOLOGY INTO TEACHERS' PROFESSIONAL LIVES

Much less is known about teachers' putting technology to use for their own purposes than about their uses of technology for teaching. There have been few experiments in which teachers have had access to technologies for their own use. We do know, however, that about 85 percent of surveyed teachers (Sheingold and Hadley 1990) had computers at home for their own use. In addition, some technology-intensive experiments, such as the program in Central Kitsap, Washington, (Sheingold 1991) and the California Model Technology School in Cupertino (Stearns et al. 1991), have emphasized teacher access to technologies for their own communication and productivity in advance of or in concert with teachers' learning about technologies for teaching. We do not yet know whether adopting technologies for their own non-teaching purposes is a necessary condition for teachers' using technology well in classrooms but we do know that it is not enough to ensure that teachers integrate the technology in their instruction. However, from the perspective of enhancing the workplace and professional lives of teachers, there is much to be said for the potential of technologies.

Teachers can use computers for their own writing and written materials, letters to parents, and so forth. They can keep track of student records with several different forms of software. They can use computers as presentation devices in classrooms and at meetings and conferences. While these are very straightforward uses of the technology, they may do more than make some processes more efficient and products more attractive. Most professionals as a matter of course now have access to computer-based technologies in their workplaces. For teachers to have them also may be an important signal that they are valued as professionals.

### Learning and Teaching About Teaching

Technologies can be used in ways that help teachers and teacher education students learn more about the teaching profession. Both video and interactive video technologies are particularly promising. The following are few examples.

Two projects for teacher education students begin with the notion that it is crucial for prospective teachers to be able to see, analyze, and reflect on real classroom teaching in the light of what they are learning in university courses. On-site observation, however, is of limited value because it happens in real-time and cannot be reviewed, replayed, or subject to alternative analyses and reflection. Moreover, the fleeting nature of real-time observation makes detailed comparisons of any kind almost impossible. What are needed, then, are useful examples of teaching on videodisc, that can then be accessed and annotated by teachers and teacher education students in multiple ways.

In work at Vanderbilt University, Elizabeth Goldman and her colleagues have created a videodisc and Macintosh with Hypercard prototype that constitute materials for an elementary mathematics education course (Goldman and Barron 1990, 1991). The materials include short video segments of elementary lessons that illustrate particular parts of the course curriculum. Typically, there is more than one example of a pedagogical approach to a particular problem. Students are encouraged to analyze the differences between and among approaches, particularly with respect to children's understanding of the mathematics. Hypercard materials include a range of information, such as teacher comments about the lesson, analyses from university researchers or other teachers, the course professor's outline, and related readings. Early evaluations of the materials indicate both that students are highly interested in the materials and that teachers who had access to the video segments during preservice were rated higher on their own teaching of mathematics lessons than a control group.

In another project, researchers at Michigan State University (Lampert and Ball 1990) are designing an interactive, multimedia prototype system to support a new pedagogy of teacher education. Magdalene Lampert and Deborah Ball teach elementary mathematics in a local school, and teach prospective elementary teachers at Michigan State. Their elementary classroom lessons, captured over one year on

video, provide rich examples of what it means to teach mathematics for understanding. This large database of taped lessons is a source of data, analysis, and reflection for prospective teachers who are trying to make connections between "analyses of good practice and the realities of life in classrooms. . . ."(Lampert and Ball) These lessons, along with annotations in multiple media and multiple links and pathways through the material, are being designed as a prototype learning environment for prospective teachers as well as a presentation tool for teacher educators. Once completed, these materials will help illustrate new pedagogical approaches and challenge long-held ideas about what constitutes good teacher preparation.

A project for the National Board for Professional Teaching Standards (NBPTS) is relevant for practicing teachers. NBPTS is developing assessment systems to credential experienced teachers in a variety of subject-matter areas at different grade levels. NBPTS is interested in the possibility that videoportfolios can contribute to the credentialing process, and is supporting research on this issue. As part of this project, researchers at the Educational Testing Service and the Institute for Research on Learning are working with teachers to make videotapes of secondary mathematics lessons, develop a revisable set of standards about what good mathematics teaching consists of, and design a collaborative process for teachers' viewing and discussing videotaped examples of teaching (John Frederiksen, personal communication). In video clubs in three schools, teachers will view and discuss each others' work, an activity that rarely occurs in the isolated world of classroom teaching. Over time, it is hoped that these discussions will help teachers develop a common understanding of what good teaching involves, improve their teaching, and assemble their own videoportfolios for assessment and credentialing purposes.

### Teacher Collaboration and Communication

While the technologies mentioned in the preceding examples are intended to promote discussion and communication among teachers and teacher education students in the same location at the same time, local and long-distance networking technologies can support communication and collaboration over time and distances. These can facilitate communication among teachers, between teachers and students, and between teachers and the community. While there are numerous systems of telecommunications now in place, there has been little systematic research on how teachers use them and how their use affects teachers' professional lives (U.S. Congress 1989). This lack of research derives, at least in part, from the fact that initial efforts have had to be devoted to basic issues of design and implementation. Research on impact is now under way for some experiments.

From the teacher's perspective, a central benefit of networking systems is that they allow for interaction with a larger community of teachers who are involved in and care about common issues and projects. Simple messaging and e-mail systems can be helpful among teachers who work together but it seems likely that more sustained collegial benefit can be obtained from participation in systems with some sort of group structure and a shared purpose for interacting (Riel 1990). The AT&T Network is a particularly interesting example because it specifically structures activities over the network in ways that support collaboration among teachers and students. It involves groups of classrooms (typically 6 to 8) in "Learning Circles." The classrooms in a Learning Circle engage over a 4-month period in projects, which are planned, discussed, shared, and published among Learning Circle members. Margaret Riel has studied the changes in teachers who participate in Learning Circles. She concludes that the network provides an environment within which teachers acquire new knowledge, develop strategies for teaching and learning, increase self-esteem, and develop meaningful relationships with their peers in network schools (Riel 1990).

## TECHNOLOGY INTEGRATION: BARRIERS AND INCENTIVES

The preceding outlines of patterns and possibilities are indeed positive. They describe a technology integration process that is also a process of professional growth and development for teachers—not only because teachers become comfortable and competent with technologies, but because, in the course of doing so, they alter their practices and beliefs in ways that can powerfully affect students' learning. Unfortunately, these kinds of changes—particularly those that most deeply affect teachers' beliefs and pedagogy—are uncommon. And so far the indications are that this process takes a long time—five to six years by one estimate (Sheingold and Hadley 1990). Before suggesting what is needed to make this process work more broadly, it is important to consider both the barriers that impede effective integration and the incentives that are in place.

Even with more than the common amount of support, teachers have experienced significant barriers to the full and effective integration of technologies.

Teachers indicate that the amount of available technology, access to it, time to plan for its use, and time for students to use it are central barriers to effective technology integration. Less experienced and less well-supported teachers encounter great difficulties; they need greater support and opportunities to learn how to use technologies for teaching. Fortunately, there are significant incentives for teachers as well. Teachers are motivated by their students' engagement with the technology; by seeing students actively "on task" while working with computers; by seeing that they are using the technology effectively for their own learning; and, in some instances, that students are doing much more challenging work with the help of technology. Also, the professional development that technology use affords teachers is deeply rewarding.

## TOWARD BROADER INCORPORATION OF TECHNOLOGIES INTO TEACHING

Clearly, technologies must become a pervasive part of teaching at all levels if its potential benefits for teaching and learning are to be realized. Large-scale incorporation of technologies, however, will take place only with significant support over a long period of time. Five kinds of support are particularly important:

1. **Technology, in plentiful quantity.** Some years from now, when we look back at these early days of technologies in schools, it is likely that we will wonder not why we didn't see a "computer revolution," but how incredible it was that so much was accomplished with so little. With limited access to technology, a great deal of time and energy is wasted in simply getting to it; scheduling and rearranging schedules so that teachers and students can have it when they need it. Teachers should have their own computers, modems, and telephones. This is a costly proposition in today's dollars. It may be that we will need laptops that are both inexpensive and sophisticated to make this vision a reality.

2. **Time**. This resource is even more scarce than technology, and it is the one that teachers need most if they are to learn to use technologies in ways that can deeply affect what they do and what their students learn. Teachers need time for their own planning, learning, and working together so they can bring technology use, pedagogy, and curriculum together in new and powerful ways for students. This will most probably only be done by restructuring the daily and weekly school schedules so that teachers have reasonable amounts of time away from teaching. Perhaps we can learn something from schools in China and Japan, where teachers are responsible for classes for only 50 to 60 percent of the school day (Stigler and Stevenson 1991). During the remainder of the day, teachers carry out other responsibilities to their students and the school. They also plan lessons and engage in both formal and informal interaction with colleagues aimed at the improvement of teaching through observing, discussing, and criticizing each others' work.

3. **Human support.** Teachers need many different forms of support, help, and opportunities to learn in the process of integrating technologies. While early on they may need more help on technology, and later more on pedagogy and curriculum, help in both arenas is required throughout the process. In addition, teachers need technical support that is readily accessible, for the inevitable technological malfunctions and for quick advice.

Although initially it may be necessary to rely on outsiders, much of this human support should be built and developed within a school. Schools should work to establish a cadre of teachers with expertise in different aspects of technology use. The advantage of this kind of distributed expertise is that what teachers become good at and good at helping others do is to use the technology for particular curricular and pedagogical purposes. The challenge is to create a structure that sanctions teachers' sharing their expertise and supporting each other within a school.

Students are often another source of in-house technology help. Students often develop technological expertise more quickly and with greater enthusiasm than many teachers. Their help can profitably be enlisted (Ringstaff, Sandholtz, and Dwyer 1991).

Even with an effective support structure within a school, teachers still need help from outside. First, as many teachers already do, they need to have access to special courses at local colleges and universities that enable them to advance their knowledge and skills. As their work with technology and teaching progresses, some also need access to subject-matter experts who can help them learn more about the content they are teaching. Second, it is important that they be able to attend local, regional, or national technology and education conferences. These are particularly useful for giving teachers the "big picture" of what is happening in the field, and helping them see how their own work fits in that picture (Carver, personal communication; L. Morris, personal communication; Herman et al. 1991). Moreover, as teachers gain expertise and confidence, it is a very valuable professional experience for them to make presentations at such conferences.

In some schools currently participating in technology-based experiments, the presence of researchers has revealed the importance of interested listeners and practical advocates.

*Interested listeners.* As interested listeners, researchers help teachers discuss and reflect on what they are doing as they change their teaching practice with technology (Bank Street College of Education 1991; Cline and Mandinach, personal communication; Polin 1990). In an informal way, their very presence helps to make the process a reflective one for these teachers. Because the researchers have time to listen, are not centrally involved in the day-to-day working of the school, are genuinely interested in learning from what evolves in the school, and understand how these developments fit into current research and theory, they can be enormously helpful in this role. Not all schools can have resident researchers but there are other ways of structuring this kind of relationship, in which both parties have something to learn from the other. A number of different kinds of school-university partnerships come to mind. Or perhaps teachers themselves, with the leadership of mentor teachers or administrators, can have regular meetings to discuss, analyze, review, and reflect on what they are doing in their classroom.

*Practical advocates.* Virtually all researchers connected with these school-based projects have found themselves dealing with the many practical problems and administrative barriers to technology use. These barriers include getting equipment ordered, making sure the order is actually sent and the equipment delivered, and negotiating about teachers' schedules so they will have time for inservice workshops and meetings. In schools with researchers, the researchers cushion many of the practical barriers to technology implementation and use. That they end up doing so much of this work illustrates how poorly these systems function under normal circumstances. Starting up seems to pose the largest number of practical problems at once; typically it takes a year for schools to order equipment, and have it in place and working.

Even when the technological system is set up, researchers still find themselves in an advocacy role, making it clear to administrators that what their teachers are doing is important, and making it clear to the teachers that their work is valued. This advocacy is needed particularly in schools where there is not a cadre of teachers using technology, and where the school and district leadership is not fully supportive of the effort. Neither the practical help nor the advocacy role are ones that researchers should or can fulfill in the long run. More institutional ways will have to be found for meeting these needs.

Given that many forms of human support are needed, it will be important to find out which can effectively be provided or enhanced via technology itself—long distance networks, video, and interactive video—and under what circumstances.

4. **Leaders inviting change and meaning it.** In a paper on technology and restructuring, Jane David (1991) points out that an invitation to change is critically important for any real change to occur in schools. Technology, she argues, can be symbolic of such an invitation, because we often see technology as a symbol of a new, different future. But technology alone is not a strong enough invitation. Leaders' support and involvement is essential for technologies to be well integrated into teaching on a broad scale.

It is not proper for a leader to determine specifically which technologies are used or prescribe exactly how they are to be used. Rather, leaders need to set the framework and provide support for the long-term innovation that technology use requires and makes possible. The framework must be one that connects technology with visions and goals for what and how students learn, what and how teachers teach, and the kinds of learning and teaching environments schools should become. The framework must both set high standards and expect and reward risk-taking and long-term effort. And it must evaluate teaching and learning in ways that are consistent with these visions and goals. Leaders must be prepared to set a tone that is consistent with the goals that they set, to make the accompanying innovations in their own professional lives, and to imaginatively incorporate technologies into their work.

5. **Systemic reform.** At almost every turn, the effective integration of technologies into teaching practice calls into question traditional assumptions about many things, such as what teaching is, what it means for teachers to be professionals, and how schools should be organized. It is the system of values, policies, practices, and organizational structures that has been the central barrier to the integration of technologies into teaching. Without systemic change that values the kinds of teaching and learning that technology integration supports, it is unlikely that such integration will ever be widespread (Sheingold 1991). In the context of broad reform, however, the stage is set for technologies to contribute significantly to the improvement of teaching practice, and, thus, to schooling in general.

## CONCLUSIONS

The presence in our schools of technologies for their own sake, once thought to be a sufficient purpose, is a goal we cannot now afford. At a time when it is widely agreed that we must aim to put in place a world-class educational system for all of our students, we must be strategic about how we choose, organize, and use our human and material resources. Teachers are the central human resources for improving our schools. In order for them to improve their practice, schools must become places where teachers' learning and professional development is valued and supported; where there is a vision about what it means for students to learn well; where teachers are invited and expected to take risks in the interests of improving students' engagement with and learning from challenging tasks; where teachers have the time and collegial structure to discuss, plan, and reflect on their own practice; and where teachers themselves are evaluated based on a newly developing set of standards for good pedagogy. Within such an environment, the integration of technologies can become a powerful mechanism for the improvement of practice, both directly as it affects learning and teaching in the classroom, and indirectly as it enhances teachers' work lives and opportunities for collaboration and communication.

It is now well understood that the challenge of integrating technology into schools and classrooms is helping teachers to participate in a process of innovation in their own teaching. Technologies are now peripheral to teaching in schools, colleges, and teacher education programs. If we want them to be central, we must aim for two goals: First, that teachers comfortably and flexibly use technologies to support and enhance student learning throughout the curriculum; and, second, that teachers can comfortably and flexibly use technologies to enhance and support their own communication, productivity, and learning as professionals.

Research on the incorporation of technology into teaching practice reveals some encouraging trends in schools where the technology-based innovation is well supported. Classrooms are becoming more student-centered and teachers are working more collaboratively and rethinking what and how they teach. Research on integrating technology into teachers' professional lives is meager, but suggests productive possibilities for practicing teachers and teacher education students.

On a broad scale, however, the barriers to integrating technology into teaching are considerable, and are not amenable to simple or quick solutions. Teachers need an adequate amount of technology, time, and human support, as well as leaders that invite change and mean it and promote systemic reform. Within a supportive environment, and as part of systemic reform, the integration of technologies into teaching can become a powerful mechanism for the improvement of practice, both directly as it affects learning and teaching in the classroom, and indirectly as it enhances teachers' work lives and opportunities for collaboration and communication.

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# Planning for the Technology-Rich Learning Environments of the Future

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## THE STATUS OF EDUCATION

In 1983, when "A Nation at Risk" was published, there was general agreement in all sectors with its conclusions that education is the primary factor undergirding the nation's prosperity and security and "that the education foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and as a people."

At all levels, we have allocated more resources to address the problems of our education system. Despite these increased resources, the general public is increasingly disillusioned by the public education process. Low SAT scores, a decrease in the number of students pursuing college, startling figures about massive illiteracy in America, and an increasing need to integrate multicultural students are all factors contributing to the loss of belief in our country's educational system. In fact, the U.S. public generally believes that education "bottomed out" in the 1980s.

Many politicians and business leaders (as well as ordinary citizens) are quick to claim that the crisis in public education is unrelated to funding. After all, controlled for inflation, public spending for education per student at all levels increased during the 1980s.[1] This theme of "money isn't the answer to the problem" became the cry of many organizations trying to grapple with the disturbing outcomes of public education.

Reform movements were instituted at all levels. President Bush's "America 2000" set new goals for education and The National Governors' Association, in their *1991 Report on Education*, recommended a "new environment designed to fit the changing requirements of the workforce." The corporate sector joined the debate on education reform with restructuring plans based on business models of organization. Arthur Andersen and Company, for example, recommended a "Systems Approach to Restructuring Education," which would abandon the Industrial Age model of assembly line education and embrace a "customer focused" Information Age model.[2] In California, The Business Roundtable urged a restructuring of public education that would "create a better environment for engaging all students in powerful learning experiences based on challenging curriculum."[3] All of these reports and many others argue that information technology must play an increasingly significant role in solving the crisis in our schools. Noted education researcher Alfred Bork summarizes:

> Education worldwide has major and increasing problems. We have the capability, using the new interactive technology, to ameliorate these problems. But this will only happen if we learn from the past to plan for the future.[4]



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## WHAT ROLE WILL INFORMATION TECHNOLOGY PLAY IN SCHOOLS IN THE YEAR 2000?

George Gilder, a senior fellow of the Hudson Institute and noted author on the future describes the role of technology in the year 2000 this way:

> Microchips will contain a billion or more transistors, expanding a millionfold the cost-effectiveness of computer hardware. The terminals on our desks and televisions in our living rooms will give way to image-processing computers, "telecomputers," that will not only receive but also store, manipulate, create, and transmit digital video programming. Linking these machines will be a worldwide web of fiber optic cables reaching homes and offices.[5]

Gilder further argues that the very nature of interactive technologies will transform our society. The challenge for education is to prepare for the new role that sophisticated, low-cost, widespread information technologies will play. We cannot afford to remain 10 years behind business in the adoption of technology developments.

For the most part, schools are still at the early adopter stage of technology. Gilder states that the first computer systems in business made companies hierarchial and centralized. Technology trapped managers, workers, and customers in top-down systems. Most people received information passively, as if from on high, through dumb terminals, simple telephone lines, and televisions. Unfortunately, this is still the status of educational technology in most of our nation's schools.

American schools do now house 2.5 million personal computers for student use, a ten-fold increase from 1983. Clearly, educators are trying to take the message of "A Nation at Risk" to heart. And yet, as Linda Roberts, Senior Associate for Science, Education and Transportation at the Office of Technology Assessment (OTA), concluded in June 1991:

> Even though K-12 schools now average 1 computer for every 20 students, most schools still do not have enough computers to make them a central tool of instruction. These gains in education pale in comparison to the information technology applications developed by business, the military, medicine, and higher education. Only a handful of classrooms have one computer for each child and another one for the child to use at home. Few schools have been built or remodeled to take advantage of interactive networking capabilities. And, while most teachers want to use computers, few consider themselves adequately prepared to teach with them.[6] (Also see Appendix A).

Even after a decade of concerted efforts to integrate technology into instruction, classrooms today resemble those of 50 to 100 years ago much more closely than today's assembly plants, scientific laboratories, operating rooms, and businesses match their equivalents from the same time periods.[7]

It is not that schools, districts, state departments of education, and federal agencies have not made an effort to infuse technology into instruction. They have. California alone has allocated over $115 million out of the general fund specifically for technology deployment in schools since 1984 (See Appendix B) in addition to other significant funds for technology from federal Chapter 1 and 2 programs, vocational and special education monies, corporate contributions, and district monies. Despite all of this effort in California, the state still ranks near the bottom in computer-student ratios.[8] Most computers are not connected to one another or outside networks of information, and teachers still use technology as a stand-alone instructional strategy, not a tool for learning.

Most other states have followed similar paths. As two OTA reports conclude, the states are becoming major players in planning, supporting, and organizing technology infusion in schools.[9] Richard Hezel, doing work under the auspices of Annenberg and the Corporation for Public Broadcasting, conducted a state-by-state survey and analysis of efforts in telecommunications technology and concluded that most states are actively planning and budgeting to infuse technology into instruction. According to Hezel, "More and more states are adopting a comprehensive approach to educational telecommunications planning. . . . State budget deficits and revenue shortages [we]re the reasons given most often in 1990 for delays in technology implementation."[10]

The key to effective infusion of technology in schools is not solely a function of spending more money for hardware, teacher training, and courseware development. Certainly, many more dollars will be needed, but the primary need is for a new way approach to technology infusion. This new approach must:

- Adopt a shared vision of the role technology can and will play in educational institutions and in society as a whole.
- Provide coordination for the implementation of the vision at the federal, state, and local levels.

- Mandate interagency and intersegmental sharing of resources.
- Guarantee equity of access to educational technology for all of our nation's teachers and students.
- Propose solutions that are technology- and hardware-neutral and stress needs-driven functions, interconnectivity, and equitable access.

## WHY A NEW PLAN IS NEEDED

Technology infusion in schools has not been properly developed and implemented partly because we have been trying to do too much, with too little, too soon. As a result, technology implementation has been far more difficult, time consuming, and costly than expected. The rapidity with which technology has changed has left generations of outmoded, incompatible pieces of hardware in our schools. Many technology projects have been oversold, making educators skeptical of and resistant to change, reactions compounded by a consistent lack of training for teachers and administrators. And, last, but not least, educators have been presented with technology-based courseware that has been intellectually and visually unexciting, and has not been linked to curriculum reform and framework efforts. This creates a situation in which teachers and students only use technology-based instruction as an add-on or augmentation to "real instruction."[11]

However, we only need look to the nation's businesses to see that these factors are not givens of telecommunications technology. Japan's decision to deploy a broadband fiber optic information network to every home by the year 2000 makes it clear that we must figure out a way to infuse telecommunications technology into every aspect of our learning and teaching endeavors, or we will not be able to meet the goals of America 2000.In fact, if we don't figure out a way, our very survival may be at stake.

## PLANNING ISSUES

There are several major issues that influence all plans to infuse technology into our schools in 1991:

1. The United States lacks a coherent vision of the role that telecommunications technology should play in supporting health and human service delivery in this country.

2. There is no easy way to integrate our technological tools.

3. Telecommunications technology is expensive to deploy at a time when education faces declining revenues at all levels.

4. Training educators to use technology is a monumental task.

5. Technology-based courseware has not kept pace with curriculum reform movements and is not easily integrated into curriculum frameworks.

### The United States Lacks a Coherent Vision of the Role that Telecommunications Technology Should Play

Futurist Alvin Toffler believes that the very survival of the U.S. democratic form of government depends on the building of interconnected, high-speed electronic networks that will form the key infrastructure of the 21st century. He likens these networks to the railroads and highways of an earlier era.[12] Most communication scholars and researchers agree with Toffler. Unlike Japan, Germany, France, and many other developed countries, the United States has lost its historic consensus on telecommunications policy, which led to the Communications Act of 1934 and its resultant universal telephone service. Since the divestiture of the AT&T Bell system almost a decade ago, our policy focus on a competitive marketplace in telecommunications technology has discouraged national planning of a universally accessible broadband network.Instead, we now have a highly competitive, multiple-vendor environment dominated by special interests and private networks. It is in this environment that educators have tried to deploy technology into schools. As a result, the kind of technology deployed in our schools for the last 10 years has been vendor-driven, with little regard for compatibility and interconnectivity. Early adopters of technology in schools, largely site-based, bought what appealed to them. As a result, the average school has various types of hardware of differing generations that exist almost as islands of stand-alone technical support for individual teachers and students who know how to use them.

Even technology visionaries at the school, district, and state levels who saw the need for networking in the areas of distance learning, teacher training, and resource management were confronted with concerns about which type of delivery system to buy, and universal connectivity, and cost. There were tough

questions to be answered at a time when demand for services was low. The result has been many good services delivered over lots of private networks with no central point of connection. Hezel's survey of existing programs and telecommunications services in the states illustrates the point.[13] It is clear that without a coherent vision of the role that telecommunications infrastructure will play in education and other elements of society it is very difficult to begin a planning process at the state and local levels.

No one in education can quarrel with the goals that President Bush and Secretary of Education Lamar Alexander set forth in America 2000.[14] But one can quarrel with the level of abstraction in the vision as to the technological infrastructure that we need to meet the goals. There is no guidance about how to get the "technology of Desert Storm" into the classroom. The Administration's solution is to support more model schools and classrooms of the future through the New American Schools Development Corporation, which is funded with over $200 million in corporate and foundation donations.[15] Educators know that we do not need more models to determine if technology assists in learning. California has funded extensively researched models at the district, school, and classroom levels (See Appendix B). Models around the country funded by Apple, IBM, Josten's, Northern Telecomm, General Telephone, and many others are too numerous to count. What we need from the Administration is a clear vision of how to equitably distribute what is known, as a result of these models, not more models.

As Roberts told Congress in June 1991:

> OTA's assessments make it clear that, under the right conditions, new interactive technologies contribute to improvements in learning—from helping to build basic skills through drills offering self-paced practice; to directing student discovery through simulations in science, mathematics, and social studies; to encouraging cooperative learning as students work together on computer projects in the classroom or on electronic networks across the continent.[16]

There are others at the federal level also trying to shape a vision. Unfortunately, they are systemically separate and disjointed. One of the problems of planning for technology at any level is that the policymakers concerned with technology and education issues exist in different departments and legislative committees. In California we must deal with The Governor's Office, The State Department of Education, The Department of General Services, The Department of Finance, eight legislative Committees, and an intersegmental education planning body even before we get to school administrators, teachers, corporate advisors, and other interested bodies. With a similar situation at the federal level, it is not surprising that there is no consensus on technology infusion in education. The status of planning for technology infusion prompted California's Chair of the Assembly Education Committee Delaine Easton to tell participants at a California Technology in Education Summit that technology advocates must "send in the clones" to every forum to frame a coherent vision.[17]

Despite the segregation of efforts and lack of a coherent vision at the federal level, there are some interesting programs and knowledgeable leaders on this issue, and in various parts of the Administration good work is being done. The National Telecommunications and Information Administration's *Telecomm 2000* is an excellent vision of the country's infrastructure needs for the 21st century. It represents a substantial effort to outline education's needs for a telecommunications infrastructure and the leadership role that the federal government must play.[18] At the Federal Communications Commission, Chairman Alfred Sikes is arguing for breaking down telecommunications regulatory constraints to encourage a rapid, widespread deployment of advanced multi-use technology that would go a long way to meeting schools' infrastructure needs.[19] In Congress, the OTA has done outstanding work with studies of technology infusion into education and its work has set the stage for good programs such as "Star Schools" and Senator Gore's current efforts on the National Research and Education Network (NREN).[20] Each of these efforts is laudable, but what we need is a national vision for technology deployment in schools—what we have are pilots, specialized grants, and other stop gap measures. As the Arthur Andersen report previously cited concludes:

> A vision for educational excellence that will capture the public's imagination must be communicated and with an impact as powerful as President Kennedy's assertion "to land a man on the moon and return him to earth within the decade." This vision should vividly describe what can and must be achieved—a school system focused on each student, with the technology and staff to support the quest for individualized instruction. A specific goal must be articulated: By the year 2000, all students will be equipped with the tools for lifelong learning, holding in their own hands the means to continue their own destinies.

The report further argues that installing a technology-rich system, along with the necessary training and materials development, in each of the nation's schools would require an annual investment of $15 billion over the next 15 years.

How do we get there from here? We must all use our national organizations and our local elected officials and corporate advisors to articulate a coherent vision. It is the same task we face on any major public policy reform. But it is a critical first step in the planning process.

Many states have a head start in vision formation. Hezel's report and Art Sheekey and Susan Douglas' excellent analysis of state planning activities summarize the state-level efforts in this area.[21] In California, we have been refining and modifying our vision for seven years. In 1991, under the mandate of new legislation to authorize and govern the expenditure of funds for educational technology, the statewide Educational Technology Summit of researchers, administrators, government officials, legislative and Governor's representatives, teachers, and corporate leaders was held to refine our vision and map out a strategic plan for the next ten years (Appendix D). The result will be several pieces of legislation on school reform and technology's role in it. Each state must begin or continue a similar process if we are to develop and successfully implement a vision for technology in education.

At the district or site level, there are as many different visions of technology's role in instruction as there are vendors to sell them.[22] This is not uncommon at the early adopter phase of technology infusion. We should not be critical of this process but we need to move beyond it and disseminate the best results of each in an equitable and universally accessible way.

## There is No Easy Way to Integrate Our Technological Tools

As discussed earlier in the paper, there is no central broadband network that schools can use to deploy telecommunications resources at the federal, state, and site levels. Additionally, the base of equipment installed at most school sites is often unconnected and incompatible with other equipment at other sites within the district, state, or nation. This technology integration planning problem results in part from the fact that most classrooms in the country do not even have a phone line or enough electrical conduit to support a networked computer configuration. Our goal should be to have a fully wired network of schools within five years. This is a massive undertaking that must be locally driven. It presents a perfect opportunity for parent groups, local businesses, corporate volunteers, and others to lend a hand to education. Phone companies and electrical utility companies in each area should be asked to plan and coordinate the renovation work.

In California, the six model technology districts each tackled this problem differently. Some had parent groups take the lead with district maintenance staff. Others used telephone and utility company volunteers (The Telephone Pioneers) to accomplish the task. One used small business volunteers from the community. There are many creative solutions to this labor-intensive, unglamorous task, all of which should be explored.

An even larger task is coordination of all the excellent data- and television-based networks such as Internet and CSUNET in California; satellite or off-air television networks such as the Star Schools funded TI-IN and TERC; and regional instruction television networks such as the Pacific Mountain Network and California's seven instructional television agencies. In the absence of a universal broadband public network to transmit voice, video, and data to school sites, many states have built their own networks. Oregon, Texas, Iowa, North Dakota, Maine, and Kentucky have all moved in this direction.[23] Some are satellite-based while others are phone-based. Some have the capacity to allow for large-scale interactivity, some do not. They are at best interim solutions. In California, we have no central network service. We are exploring various options.

The real problem with this approach is that the solutions at a state or district level are very expensive and, if constructed in this fashion, education must bear the cost of the entire deployment of a network that is likely to be inadequate for our needs before it is built. I believe the real solution that educational technology planners must strive for at the state and federal levels is the deployment of a broadband fiber optic network to every school (and ultimately, home) in the country. I agree with Toffler, Gilder, and NTIA when they argue that telecommunications technology must be viewed as essential infrastructure.

If a broadband network were deployed as a matter of federal industrial policy, education alone would not have to bear the cost of network deployment. As Hezel notes in his study, some states, including Maine and Michigan, have already learned this lesson and are splitting costs with other public sector information providers and regional telephone companies. For states like Kentucky, which has opted for a satellite-based system, and Texas, which subscribes to the off-air broadcasting and microwave-delivered network

configuration, the deployment of a universal broadband network would allow for much larger capacity, interactivity, and a centralized gateway configuration that existing state networks could be housed on.

All of our technology plans must address this key issue. We must educate our constituencies about the potential for such a network (interconnectivity, interactivity, adequate capacity, protocol conversion, uniform access for all, and central display of learning resources on a gateway of information services). We must also influence policymakers at all levels to see the wisdom of such a choice as the political climate is changing on these infrastructure deployment issues. In July 1991 the barrier to phone company participation in information services was lifted by the Federal Appeals Court. The Chairman of the F.C.C. favors a wide deployment of broadband information services. Our planning must include actions that allow our voices to be heard in this debate.

### Telecommunication Technology is Expensive to Deploy at a Time When Education Faces Declining Revenues at all Levels

When considering either Gilder's estimate that it would take $200 billion to deploy a broadband fiber optic network in the United States, or Arthur Andersen's estimate that it would take $15 billion per year for five years to provide schools with adequate hardware, courseware, and the training to use them properly, it is easy to see that the cost of creating technology-rich learning environments is enormous. That is why we must concentrate our planning at the federal and state levels. That is why technology infusion must be raised to the rhetorical level of the "Apollo" Moon Project. We will need all of the nation's forces behind us if we are to accomplish this task in an equitable way in our lifetimes. As a recent Rand Corporation report concludes, education's problems are too severely intertwined and entangled with broader community, social, and economic events to be solved by the traditional education bureaucracy."[24] Our plans must reach out and include all segments of education and other public information providers, telecommunication industry experts, corporate leaders with experience in infusing technology in business, and policymakers at all levels. This is often uncomfortable for educators to do because we tend to be insular and protective of the sanctity of our endeavor, but, as American Federation of Teachers President Al Shanker told the *New York Times*: "Our persistent educational crisis shows that we've reached the limits of our traditional model of education."[25] Shanker went on to say that: "A national telecommunications delivery system could help us transform education in all local schools. Providing teachers with a wide range of databases and available video programs, which would be a great force for educational improvement. . . . Putting this technology into every classroom so every teacher can use it . . . must be a priority for the new decade."

### Training Educators to use Technology as a Tool for Learning is a Monumental Task

So often in our planning process for the infusion of technology into instruction, we underestimate the time and resources necessary to educate our workforce to use technology as a tool for teaching subject-matter curriculum. In the early adopter phase of technology diffusion, participants are motivated and generally not "technophobes."[26] However, as technology spreads through an organization, the need to continuously train workers becomes paramount.

In California, we have struggled with this issue repeatedly. We have tried several models, regional training and technical assistance centers, and, most recently, a university-based ITFS and database system supported by regional consortia. Both models seem to work (see Appendix B). The key to each is adequate funding and sanctioned released time for teachers to participate. A state network or broadband public network could make the delivery of training materials a much simpler task. All states seem to be struggling with the problem in ways similar to California. The lesson that we have learned for planning purposes is to budget roughly 1/3 of every dollar spent on technology hardware for training.

Any plan, be it site-based, statewide, or national, must budget enough money to adequately train all teachers and administrators to use technology as a tool. So often, we have failed to give serious enough weight to this issue. If we are really going to make technology available at every site and to every teacher, and if technology is going to be a tool to transform or restructure schools then we cannot afford to underestimate this effort. As Sheekey and Douglas argue:

> With respect to education technology-based programs . . . too often advocates for new technologies are attempting to outflank classroom teachers by developing teacher-proof materials. . . . Studies confirm the fact that a much greater degree of success is assured when teachers are involved in the early stages of planning and when teachers are given adequate training, support, and appropriate incentives. (Sheekey and Douglas, p.73)

We have learned with our model school in California that we cannot develop plans without involving teachers and other site-based personnel.

### Current Technology-Based Courseware Has Not Kept Pace with Curriculum Reform Movements

One of the most difficult tasks for technology planners in education is to ensure that once the hardware is in, there is something worthwhile to access. Computer-based learning materials and instructional television programming have come a long way in the last ten years but even greater development has been hindered in part by the lack of an installed base large enough to guarantee a market for publishers and developers. A related problem has been gearing off-the-shelf programming to curriculum frameworks. Consequently, early adopters of technology in schools worked with what was available from vendors and adopted as they could.

As more teachers use the courseware this problem will decrease. California has aggressively pursued statewide licenses for programs to guarantee their availability to all schools without copyright violations and at a cost based on economies of scale (Appendix B). California changed the financial constraints on textbook adoption so that districts could use textbook funds to acquire technology-based learning materials. Texas led the way in this area. All states should take similar steps because it sends a message to publishers and developers that technology-based materials are essential parts of instruction.

Any planning process must take into account all of these elements of courseware acquisition, management, and development. Administrators, teachers, curriculum specialists, publishers, and producers must be involved. One interesting anecdote has come out of California's efforts. State Superintendent Bill Honig was concerned that none of the courseware that he reviewed in science met the objectives of the new state framework in science. After much quizzing of publishers, he concluded that the state should lead the way in conjunction with the best and brightest developers and publishers. In order to jumpstart the production of better instructional resources, the state allocated $500,000 as seed money, in an open bid environment, to develop history/social science materials for grades 5-12. In conjunction with site-based teachers, university researchers, and corporate wizards like Lucas Films, Apple Computer, and The National Geographic Society, GTV was created (see Appendix B). This multimedia product is geared to the new state framework in history/social science, and is a huge success. Lucas Films recouped their costs on the project in the first six months of sales. We have since embarked on similar efforts to develop a complete multimedia course for 7th grade science and have just sent out a Request for Applications for a complete history/social science course in Ancient World History for sixth graders.

## FUNDING THE VISION AND THE PLAN

Once we have addressed all of the issues surrounding the statewide planning process, where do we get money to fund the plan? We are never going to be able to fund equitable access to telecommunication technologies in all of our schools as an add-on or from traditional sources of education monies. Any plan must acknowledge this up front and argue for new funds. We must plan for and join the national telecommunications policy debate at the federal level. And we must help develop and support an industrial policy that would target the deployment of a universal broadband fiber optic network to every school in this country. We need a funding plan based on direct federal support, permissive regulatory policies, and tax incentives to encourage telecommunications industries to deploy such a network by the year 2000.[27]

At the state level, we must begin interagency arrangements with other public information providers so that the costs of such a network can be shared. We must also include telecommunication companies in our planning to ensure adequate capacity, functionality, and perhaps accelerated deployment based on a shared costs model. However, while we wait for planning and consensus to be reached on a new industrial policy that addresses telecommunications as essential infrastructure, we must continue to plan for and fund existing programs of hardware acquisition, workforce training, and courseware acquisition and development.

One excellent source book on funding opportunities is *The Educator's Guide for Developing and Funding Educational Technology Solutions*, which has been put together by John Cradler, a research associate at Far West Laboratory who California hired to evaluate all of its educational technology programs.[28] Cradler reviews federal funding from technology-based sources such as "Star Schools" and the National Science Foundation and explores the use of Chapter 1 and Chapter 2 funds as a source of support for technology-based learning. He also reviews foundation and corporate sources.

Additional potential sources of funding, not covered by Cradler, include the new Literacy Act of 1991, America 2000, and the New American Schools Development Corporation grant programs. At the state level, it seems clear that most states are tapping general fund monies to the maximum. According to Cradler, districts and schools are using a combination of federal, state, local, foundation, and corporate

partnership monies to fund their projects.[29] One message is clear, we must all be entrepreneurs and innovators if we are to fund the vision of equitable access to a technology-rich learning environment.

We have tried all of the possible permutations of funding for our efforts in California. The one that seems to be the most successful is one that requires state dollars to be matched by federal, district, or private contributions or in-kind resources. This allows the state to leverage scarce funds and forces site-level planners to explore nontraditional funding arrangements with business, industry, and foundation donors. The key to the success of this kind of program is to train school-site personnel and to promote buy-in and matching funds at all levels.

## CONCLUSION

I have outlined five core issues that must drive the planning process for the technology-rich learning environments of the future. I have also suggested potential ways to fund our vision of the future. I have not suggested a specific plan because it would be presumptuous of me to do so.

If consensus on a national vision is forged, then each state must assess its needs in the context of that vision. I can only stress that we must all focus on equity of access to a technology-rich learning environment for all of our students and teachers. As Toffler says, not to do so imperils our very democracy.

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[19] Sikes, Alfred C. "Brink of a Revolution," *Newsweek* January 14, 1991, p. 8.

[20] U.S. Congress. U.S. Senate Bill 1067. April 4, 1990.

[21] Sheekey, Arthur and Douglas, Susan G. "Telecommunications: The Critical Resource for Achieving National Educational Goals, Education Policy and Telecommunications Technologies," U.S. Department of Education, May 1991, pp. 71-83.

[22] There are numerous descriptions of successful technology applications in schools. The National Foundation for the Improvement of Education's Image in Action describes common themes of technology infusion and seventeen programs that embrace them. OTA's "Power On!" and "Linking for Learning" contain many excellent examples. In California, (Appendix B) many excellent programs exist.

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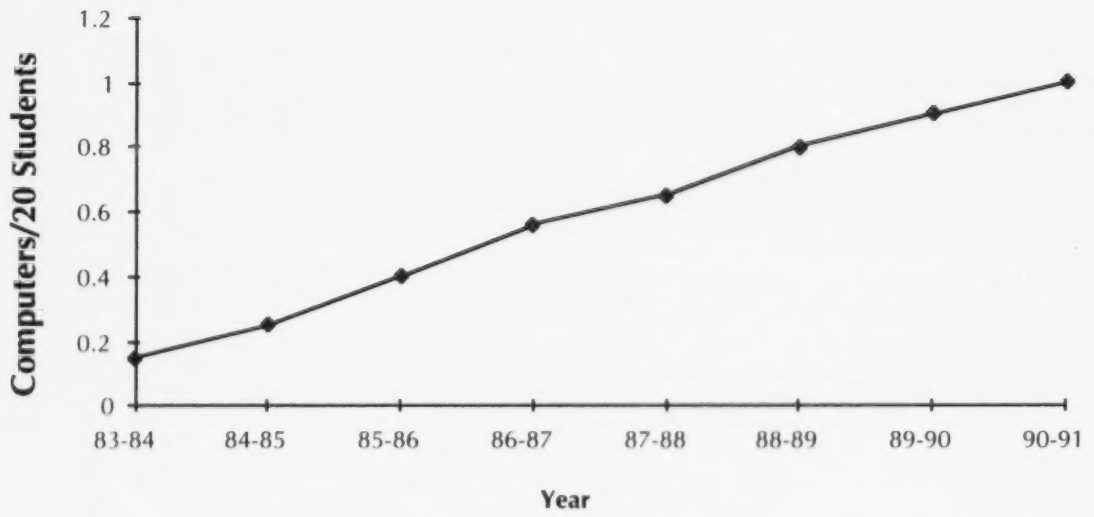
# Average Number of Computers Per 20 Students in U.S. Public Schools, 83-91



# California Educational Technology Program Highlights 1984-90

Assembly Bill 803 (Chapter 1133, Statutes of 1983); the Educational Technology Local Assistance Program; Assembly Bill 1470 (Chapter 1334, Statutes of 1989) as amended by Senate Bill 1201; and the Farr, Morgan, Quackenbush Educational Technology Act have provided approximately $115 million for educational technology programs and activities since 1984. Funding priorities were set by the State Board of Education and the Educational Technology Committee, which was established in Assembly Bill 803 and continued in Assembly Bill 1470. Assembly Bill 1470 also established the California Planning Commission for Educational Technology, which is responsible for developing a state master plan for educational technology prior to January 1, 1992. The major programs and activities funded from 1984-90 are:

## Adoption/Adaptation/Expansion Grants

Approximately $66 million has been used to fund over 600 site-based grants to encourage schools to begin or expand their efforts to improve instruction through the use of educational technology and to facilitate the completion of district-level technology plans.

## Level I Model Technology Schools

Six Level I Model Technology Schools are receiving $500,000 per year over a five-year period (the schools are currently in their fourth year) to create models of technology use for improving all aspects of the school environment. Important to the overall process is the development of business and research partners at each site. These projects are expected to produce information on the use of technology as a tool in improving curriculum, instruction, and administration for educational decision makers at both the state and local levels. After five years of funding to produce research-based instructional data, the sites will become centers for dissemination, demonstration, and training.

## Level II Model Technology Schools

Initially, ten projects received an average of $80,000 per year for two years to use technology in specific subject areas at specific grade levels. Each project focused on aligning instruction with the state's curriculum frameworks and was expected to produce educational products (e.g., curricula, lesson plans, and training) for other California schools to adopt or adapt. Currently, six of these projects have received additional funding for dissemination purposes.

## Instructional Television Regional Agencies

Seven instructional television regional agencies receive grants, with amounts based on the number of students enrolled in each region, to broadcast curriculum-relevant instructional television series. The agencies: (1) distribute program guides listing broadcast times and descriptions of programs, (2) maintain duplicating services that allow schools to purchase video cassettes, and (3) conduct extensive staff development programs. The agencies offer video programming and support services that enhance curriculum in virtually all subject areas.

## Instructional Materials Development

Program funds are used to establish partnerships between developers and the California Department of Education in order to produce technology-based materials that are consistent with the state's curriculum frameworks. These grants are intended to bring to the marketplace technology-based instructional programs that would not otherwise be developed, at least in the short-term. All local educational agencies and all non-profit or for-profit companies are eligible to compete for the development grants. The products are to serve as models for all publishers of instructional materials. Three award-winning products are already available:

1. GTV, the American Experience: A Geographic Perspective, was produced by the National Geographic Society in collaboration with Apple Computer, Inc. and Lucas Films Learning Systems. The program combines computer graphics, laser disk technology, and text.
2. World Geograph, produced by MECC, develops students' study skills such as acquiring, organizing, and interpreting information. Students use this tool to acquire and produce in-depth information pertaining to all countries.
3. Explorations in Middle School Science: The Physical Science Program, produced by Josten's Learning Corporation, consists of 36 computer-simulated laboratory activities for grades 6-9 keyed to what students are learning in the classroom.

The newest program is Science 2000, a complete technology-based resources management system for teaching science in grade 7. The resources management system is aligned with the California *Science Framework* and demonstrates how a variety of materials and programs (e.g., computer software, films, video, audio tapes, disks, hands-on materials, text, and telecommunications) can be configured to provide students with opportunities to experience an optimal science curriculum. Decision Development Corporation, in partnership with the National Geographic Society, Dinamation Corporation, IBM, Apple Computer, Inc., the University of California at Irvine, Pacific Bell, and several school districts in California, developed this program.

All contractors provide substantial matching funds. California schools receive discounts, and the state receives royalties and other services for schools, based on the companies' out-of-state sales.

### California Technology Project

The California Technology Project was initiated in the spring 1989 as a partnership between the California Department of Education, the California State University system, county offices of education, and school districts. The California Technology Project serves as a coordinating mechanism for a wide variety of decentralized, technology-oriented, educational services throughout the state, including:

1. Locally planned staff development programs and extensive school-based planning services and program implementation assistance, provided under the auspices of 13 regional consortia and councils.
2. Cooperative pilot projects with the state's subject-area curriculum projects.
3. Electronic communications networking via CSUNet/TRIE (Technology Resources in Education) with three primary components/programs: information resources (e.g., data on exemplary materials), electronic conferencing, and electronic mail services.
4. Information collection/assessment/evaluation support, including state-of-the-art school surveys, reports, and evaluation guides.

### Instructional Television Licenses/Program Acquisitions

This program has used more than $1.5 million to acquire multi-year licenses for approximately 50 ITV series and 2 computer-software packages in order to decrease costs to individual schools. These license agreements encourage extensive legal use of high-quality video programming. The selection process for materials is carefully coordinated with existing curriculum priorities, identified gaps in available programs, and the needs identified by teachers, media directors, and ITV personnel.

### California Video and Software Clearinghouses

The clearinghouses, with the assistance of county media centers and regional software preview centers, evaluate K-12 video, software, laser disk, and CD-ROM materials to determine their consistency with the state's curriculum frameworks and exemplary instructional practices. The resulting data are provided to schools across the state via CSUNet, the primary dissemination vehicle.

### VCR Distribution Project

During the summer and fall of 1985, the state purchased and distributed more than 7,000 VCRs; one to every school in California. The county offices of education provided training to the schools on use of the VCRs.

### Technical Assistance Grants to Teacher Education and Computer Centers

The Teacher Education and Computer Centers (TECC), which no longer exist, received funds based on student attendance in their regions to provide information and planning assistance to districts and schools applying for and receiving educational technology program grants. The centers also provided demonstrations to school and district personnel on the use of technology in the curriculum.

### Technology in the Curriculum (TIC) Guides

The state, with the assistance of the Teacher Education and Computer Centers, developed resource guides in six curriculum areas. Each guide included a curriculum outline, annotated descriptions of software and video materials, model lesson plans, and information on how to obtain the resources. Each school received a set of guides.

### Summer Technology Training Institutes

From 1985 through 1987, institutions of higher education received grants to provide four weeks of intensive instruction to cadres of teachers and other education professionals during the summer and to provide follow-up support during the school year.

### Teacher Training Video Project

In 1987, the Sacramento Educational Cable Consortium received funding to train and support 35 high school teachers in the Sacramento area. With training in video production design and filming techniques, these teachers produced more than 100 programs that were distributed via cable television.

### The Institute of Computer Technology

The Institute of Computer Technology is a unique California program devoted to computers education. Located in Santa Clara County, the Institute was formed by the Freemont Union High School District, the Los Gatos-Saratoga High School District, the Sunnyvale School District, and over 50 technology companies to provide technological training, facilitate the use of technology in education, foster cooperation between industry and education, and experiment with innovative techniques and computer applications. Although the Institute for Computer Technology has received educational technology funding, it was established under separate legislation and is not a program administered by the Department.

### Other Projects and Activities

The California State University Chancellor's office received a grant for the Mechanical Universe project to train high school physics teachers. The Educational Telecommunications Network (Los Angeles County Office of Education) provided staff development via telecommunications; and a variety of dissemination and communication activities were supported with program funds.

### IBM Business Partnership

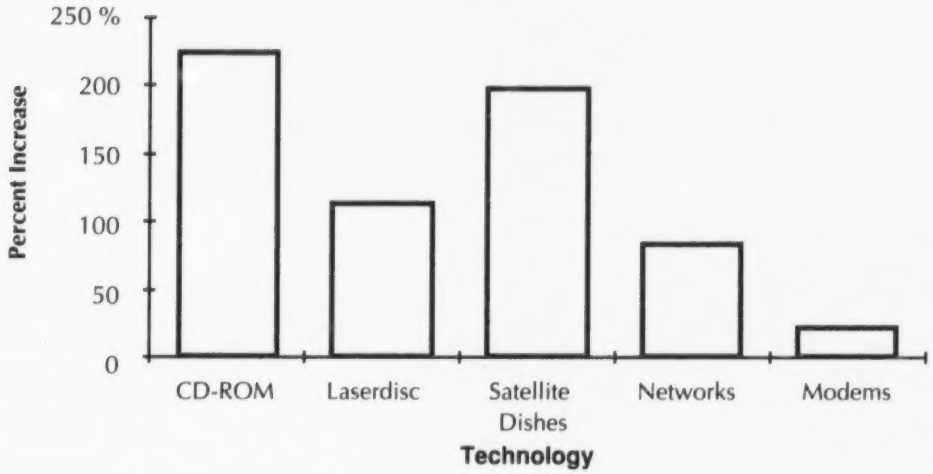
Although not funded by the Educational Technology Act, the IBM California Education Partnership projects are generating a lot of excitement in California. IBM has committed $20 million in equipment, software, and technical support to the two-year partnership. The California Department of Education, the state's local educational agencies, and the California State University system are contributing executive and technical support. The major components of the partnership are:

1. Joint development projects for creating multimedia instructional materials and teachers' guides aligned with California's curriculum frameworks.
2. Staff development laboratories in selected schools, districts, and county offices of education to serve as curriculum libraries where teachers can review technology-based instructional materials.
3. A pilot telecommunications network that links the California Department of Education, over 80 school district superintendents, and 20 California State University campuses.
4. An IBM employee volunteer program that encourages IBM's 21,000 active employees and 5,000 retirees in California to get involved in supporting education.

*1991-92 funding for the Farr/Morgan/Quackenbush Educational Technology Act of 1989 is $13.96 million*

For additional information, call or write the Office of Educational Technology, California Department of Education, 721 Capitol Mall, Sacramento, CA 95814. (916) 657-5414.

# New Technologies in K-12 Education 3-Year Trend




Number of School Districts

| Technology | 88-89 | 89-90 | 90-91 |
|---|---|---|---|
| CD-ROM | 429 | 810 | 1,376 |
| Laserdisc | 472 | 921 | 1,047 |
| Satellite | 1,068 | 2,336 | 3,149 |
| Networks | 1,567 | 2,227 | 2,873 |
| Modems | 2,723 | 3,316 | 3,360 |

Sources: Quallity Educational Data, Denver Colorado
K-12 Public Schools, Instructional Use

# Assembly Bill 1263
# A California Strategy for Educational Reform

## CHAPTER 1: A VISION FOR CALIFORNIA SCHOOLS

### ARTICLE I. VALUES AND GOALS

1. California will develop and maintain world class schools which allow its students to compete successfully on a global basis in the 21st century.
2. California's schools value students from all cultural backgrounds and design curriculum and training to maximize California's multicultural democracy.
3. California will prepare a strategic plan to achieve the national education goals developed by the President of the United States and the National Governors' Association in this century. These goals are:
   A. Creating better and more accountable schools for all pupils.
   B. Ensuring that, by the year 2000, all children will start school ready to learn.
   C. Increasing the high school graduation rate to 90 percent by the year 2000.
   D. Ensuring that pupils demonstrate subject matter competency in English, mathematics, science, history, and geography, so that they are prepared for responsible citizenship, further learning, and productive employment in our society.
   E. Ranking first in the world in mathematics and science achievement by the year 2000.
   F. Offering a disciplined environment at every school in America which is conducive to learning and free of drugs and violence.

### ARTICLE II. FINDINGS AND DECLARATIONS

A. The Legislature finds and declares that if California is to secure a defensible position in the global economy, its children must be educated for responsibilities more challenging than ever before.

1. Public education will be called upon to deliver significantly more than at present.
2. There is a need for material change in the way education is organized, operated and delivered.
3. It is time to put urgency behind better education, and the California Strategy for Educational Reform is a blueprint for doing so.

B. The Legislature finds and declares the following challenges faced in California's schools:

1. California's school population, already the largest in the nation, is growing more rapidly than that of any other state. Enrollment increases average 145,000 a year.
2. More than one out of five California children lives in poverty and the proportion is growing. Most impoverished students in California are from working families.
3. Family structure for California children has changed dramatically since World War II; the increase in single parent households and two-earner households often means parents have less time to participate in their child's learning process.

C The Legislature further finds and declares the following evidence of poor performance in California's schools:

1. The 1989 dropout rate by ethnic group, as reported by the State Department of Education, was as follows: African American, 47.7; Hispanic, 46.1; Asian, 13.7; Filipino, 13.4; American Indian, 34.8; and White, 28.1.
2. In 1989, the California Assessment Program scores of minority pupils in grades 3 and 6 averaged at least 25 percent lower than the average achievement of white pupils; in grades 8 and 12, that average difference in pupil scores slipped to 45 percent or more.
3. In 1986, the eligibility rates for African American and Hispanic high school graduates attending the University of California were 4.5 and 5.0 percent, respectively. The eligibility rate for all high school graduates was 14.1 percent.

D. The Legislature further finds and declares the following changing demographics in California:

1. By the year 2000, 58 percent of California's children will come from Hispanic, African American, or Asian families.
2. California has the largest number of immigrant children in the United States. One in six of California school children was born in another country.
3. One of six of California's students come to school not knowing English. By the year 2000, one half of California's children ages 10-18 will be Hispanic or Asian. Although, they want to learn English, California is short 20,000 bilingual teachers.

E. The Legislature further finds and declares the following principles of reform:

1. Student achievement is the focus of California schools.
2. The school site is the critical location for educational change and the most important relationship in the learning process is that between teachers and pupils.
3. Parent-school partnerships are critical to improving student performance in school. Such partnerships are enhanced by the schools serving as a site for additional community services.
4. Training and development opportunities should be available to administrators, teachers, staff, and parents.
5. Multicultural diversity is a valuable resource for each school in its efforts to become a world class institution.

## CHAPTER 2
## RESPONSIVE AND RESPONSIBLE SCHOOLS

The core tenet of this Act is that the strategic unit of public education in California is the individual public school, not the State Department of Education and not the school district. To the greatest extent possible, decision making authority will be vested in the teachers, staff and parents of the strategic units, the local schools.

### ARTICLE 1. SHARED DECISION MAKING

**School-based Management.**

A. By January 1, 2002, each school site shall be governed by a management team located at the site, in conformance with guidelines and criteria adopted by the district governing board. At a minimum, site management teams shall be given the authority over:

1. Organization, selection and division of responsibility for decision-making at the school site, including the role of certificated and non-certificated personnel, parents, students and administration.
2. Adoption of curriculum, subject to Sections 51210 and 51220 and other applicable provisions of law.
3. Organization and scheduling of instruction.
4. Selection and purchase of instructional materials and equipment.
5. Design and implementation of an annual budget for the school site, and a plan to manage the programs authorized in that budget, consistent with the funds apportioned annually to that school by the district governing board.
6. Hiring of candidates to fill certificated and classified positions located at the school site as vacancies arise as well as evaluating existing employees.
7. Development of a five-year site plan for the school which takes into account enrollment projections for the school subject to approval by the district governing board.

B. By June 30, 1993, each school district shall submit its district strategic plan to the Superintendent of Public Instruction(SPI) and notify the SPI of the timetable planned for phasing in the decentralization of management and budget responsibility.

C. By June 30, 1995, each district shall have at least one school that is governed by a site-based management team.

D. By June 30, 1999, at least 75 percent of the schools within each district shall be governed by a site-based management team.

**Team Building:**
**Public Employment Relations Board.**

A. In accordance with the purposes of this act, the State Department of Education is encouraged to give priority for participation in the programs set forth in the act, to school districts in which the governing board, district administrators, the exclusive representative of the certificated employees, and the exclusive representative of the classified employees have completed workshops, seminars, or other training in the interest approach method of resolving employer-employee conflicts.

B. Under the authority of the Public Employment Relations Board, the School Employer-Employee Relations program is established. The office shall be funded from existing resources, and shall have the function of promoting positive working relationships within school districts.

C. Notwithstanding any other provision of law, the program may do all of the following:

1. Make available to governing boards, school administrators, employees and employee organizations a training program in the use of the interest approach method to improve communications and resolve disputes within school districts.
2. Establish standards and procedures for training and certifying instructors, facilitators, and other practitioners of interest approach techniques to collective bargaining teams, labor relations personnel and personnel managers in school districts. Such procedures shall include training in the different cultural methods of communication and decision-making.
3. Seek grants and contributions from public or private sources to implement this program.
4. Contract with parties or entities seeking to provide training for school district negotiating teams in the interest approach negotiating method.
5. Monitor, assess, and coordinate research on the results of such training in this state, including the effective participation of people from different cultural backgrounds.
6. Serve as a liaison with other states, the federal government, and organizations involved in improving employer-employee relations in public education.

**Team Building:**
**State Department of Education.**

A. The Department of Education shall initiate a grant program to promote training in non-adversarial bargaining. Any school district or county superintendent of schools may apply to the SPI for a-matching grant in order to reimburse a percentage of the training costs of non-adversarial bargaining. The SPI shall develop a reimbursement schedule by district size with smaller districts being reimbursed a higher percentage of costs. The SPI shall review all applications and make grants to those local agencies displaying the greatest need and most potential for benefiting from the training.

B. Grants shall be made from funds appropriated in this act or in the annual budget act.

## ARTICLE 2. SCHOOL-BASED FINANCE

**School-Based Budgeting.**

A. The governing board of each school district shall develop a method to decentralize its budget process, or a portion of its budget process, no later than June 30, 1995, so that budgetary guidelines, priorities, and goals established by the governing board are implemented at each school within the district by the school management team for that school.

B. That implementation shall include the authority on the part of each school management team to distribute and expend, for operation of the school, those funds apportioned to the school by the governing board, and accountability to the district for those funding decisions.

C. The SPI shall convene a committee to develop guidelines for districts to use in their decentralization of the budget process. The committee shall:

1. Include, at a minimum, representatives from parent groups, teachers, administrators, board members, superintendents, professional organizations, and state agencies including the Department of Finance, the Legislative Analyst Office and the State Controllers Office.
2. Be chaired by the California Department of Education, and the department shall have final decision authority with regard to the content of the guidelines.
3. Produce a series of reports and guidelines to districts, the first of which shall be issued by June 30,1992, with all guidelines to be issued by June 30, 1993.
4. Examine and make recommendations on exemptions from the requirements of this article from small school districts.
5. Develop guidelines which shall at a minimum: (a) Provide models of decentralization; (b) Identify cost factors involved in implementation; (c) Address data processing support needs and funding options to meet the identified needs; and, (d) Include an implementation plan, including staff training and ongoing assistance.
6. Recommend minimum decentralized budget and accounting requirements to be adopted by districts.

D. A school operating under an approved school strategic plan may petition the governing board to assume budget responsibilities, pursuant to the district strategic plan. Governing board approval shall be given if:

1. The school site council has demonstrated an ability to successfully manage the operations of the school.
2. The school site council has sufficient expertise in budgetary matters to undertake school based budgeting.
3. The district maintains accounting systems that permit school-level data needed for the site council to make decisions and track expenditures.
4. The school plan conforms to the budgetary guidelines, priorities and goals established by the governing board pursuant to subsection (a).

**Student-Based Finance.**

A. By June 30, 2002, all elementary, middle, and high schools within a district shall receive the same proportional share of base revenue and categorical funds from the district for that type of school.

B. By June 30, 1996, each school district shall submit to the SPI a schedule for reaching proportional funding required in subsection (a). This schedule shall describe the percentage of base revenue and categorical funds that will be subvened to the school site, any phase-in period, and other information as required by the SPI.

### Article 3. School-Site Discretion

**Review statutory and Regulatory Requirements Imposed on Schools.** In order to provide schools with greater local discretion, the State Department of Education is directed to report to the Legislature recommendations of statutory and regulatory requirements which should be removed for schools practicing school-based management. The report shall be due January 1, 1993.

**Additional Powers.** Similarly, in order to provide schools with greater local discretion, the State Department of Education shall report to the Legislature on authority which should be explicitly granted to schools or school districts, including but not limited to the textbook adoption process. The report shall be due January 1, 1993.

### Article 4. Training

A. The State Department of Education shall provide training to school districts in developing district guidelines for school-based management plans. A sum of $____ shall be provided for that purpose.

B. Beginning in 1992-93, the SDE shall provide for training to be given to schools on school-based management and the development of school-based management plans.

C. Training to districts and schools shall include leadership development for the parent community which recognizes multicultural differences in communication and decision-making so as to allow the full and effective participation of people from all cultural backgrounds.

## CHAPTER 3. PERFORMANCE PLANNING AND ACCOUNTABILITY.

### Article I. School Strategic Plan

**Implementation of School-Based Decision Making and Finance.**

A. Prior to the implementation of school-based management, at each school, the principal, certificated employees of the school, classified employees of the school, parents and guardians of pupils attending the school and members of the local business community jointly shall select a management council for that school. Each of these groups shall be represented on the council. The relative representation on the council shall be determined by each school, subject to the minimum requirements imposed by the governing board in its district strategic plan. Representatives on the council shall be selected from within the groups of employees, parents, and businesses represented on the council. To the extent feasible, parent representatives on the council must reflect the multicultural diversity of the student population of the school. Any school that offers instruction in grades 9 through 12 shall include at least one student representative on the council, which would be selected by students enrolled at the school.

B. Once a school site council is formed, the council shall petition the governing board for approval to begin development of the school's strategic plan.

C. Upon receiving the governing board's approval as a school site council, the council shall substitute for school councils pursuant to Section 52012 (School Improvement Program), Section 52852 (School-Based Program Coordination Act), Section 54724 (Pupil Motivation and Maintenance Program), and Section (Staff Development (SB 1882), Section ___ (GATE). Funds made available to these councils shall fund the planning and implementation of school strategic plans.

D. Each school site council shall develop and submit to the district's governing board for approval a school strategic plan that describes the steps each school proposes to take to improve student achievement and implement decentralized management and budgeting. This plan shall include at least the following:

1. The performance goals the school expects to meet within three years. These goals should be based on the performance measures identified in the district strategic plan.
2. The long-term goals for improving pupil achievement at the school, based upon the particular needs of the students attending or likely to attend the school.
3. Proposed methods to improve student achievement in the subject areas specified in Sections 51210 and 51220, as appropriate.
4. Proposed methods to improve the employment skills of students, if appropriate.
5. A schedule of workshops for members of the site council and other interested parties that is designed to improve school management skills and understanding of multicultural differences in communication.
6. A list of the statutes, regulations and other requirements that must be waived or revised in order to implement the school management plan.

## Article II. District Strategic Plan

The governing board of each school district shall develop and approve, by June 30, 1993, a long-term strategic plan for decentralizing decision making and budgeting. This plan shall reserve only serve-and-support functions for the district staff while guiding the orderly assumption of decision-making by school-based management teams. This plan shall describe the way in which the district plans to decentralize its operations, the responsibilities that will be decentralized from the district to the school site, and the estimated timelines for achieving decentralization to the school site of management and budget functions in all schools within the district. The plan also shall include:

**Guidelines for Implementing School-Based Decision Making and Finance.**

A. Guidelines for schools within the district to follow when devising a school strategic plan. This shall include a statement of the district's goals for decentralization and student achievement.

B. Performance measures the governing board will require each school to set goals for in each school strategic plan.

C. Criteria the governing board will use in evaluating and approving school strategic plans.

D. Minimum requirements for the composition of school site councils.

E. Training in management and budgetary practices and multicultural differences that will be provided to administrators and teachers in order to facilitate implementation of decentralized decision making and budgeting.

F. The way in which the governing board will monitor and evaluate implementation of the school strategic plans and the school's success in meeting the goals identified in the school's strategic plan.

G. Performance goals for those functions provided at the district level including the usage of technology in the classroom, training, financial management, and curriculum improvement.

## Article III State Strategic Plan

By October 1, 1992, the Superintendent of Public Instruction shall develop and approve a long-term strategic plan for the State of California. The plan shall include timelines for achieving the goals described in this bill. The plan also shall include:

A. Guidelines for districts to follow when devising a district strategic plan. This shall include a statement of the state's goals for decentralization and student achievement.

B. Long-term goals for improving student achievement in the state, based upon the needs of the multicultural population of the state.

C. Reduction in the administrative workload resulting from required reports, which are redundant and/or of questionable use.

D. Training in management, budgetary practices and multicultural differences that will be provided to school districts in order to facilitate implementation of decentralized decision making and budgeting.

E. Increasing the quality and relevance of vocational and technical education provided by high schools and regional occupation programs.

F. Establishment of a California Center for Educational Technology (CCET), which shall collaborate with the private sector, universities and other educational institutions, to improve the quality and utilization of educational technology.

## Article IV. Accountability and Reporting

### Uniform Reporting.

A. Beginning January 1, 1993, each school shall report annually to the governing board of the school district the following data on the school year completed the previous June:

1. California Assessment Program — or any standardized test mandated by the state — scores for each grade level.
2. Dropout rates, if appropriate.
3. Attendance rates.
4. Student completion of specified courses.
5. Percent of students enrolled in a-f courses, if appropriate.
6. Average class size.
7. Teacher experience.
8. Number of suspensions.

B. Beginning June 30, 1993, the governing board of each school district shall annually submit to the state superintendent of public instruction all data described in (a).

C. School report cards (required by Proposition 98) shall contain at least the data describing each school's performance in the areas identified in (a).

### Financial Accounting.

A. Budgetary information shall be made available to members of the general public, with special attention to the information needs of parents and guardians of students attending school. In order to accomplish this, by March 1, 1992, the Superintendent of Public Instruction shall develop, in accordance with Chapter 1 (commencing with Section 41000) of Part 24, a model to be used by public schools that will, at a minimum, capture expenditure and staffing information.

B. By November 1, 1992, and each year thereafter, each district shall issue to the public, and submit to the California Department of Education, a uniform accounting of the prior fiscal year's expenditures for schools within the district using the model developed pursuant to subsection (a). This report, shall at a minimum, reflect the average within the district but may be completed for the average elementary and secondary school. The CDE shall publish this information for all districts in the state by September 1, 1993.

C. By November 1, 1995, and each year thereafter, each district shall make available to the public, and submit to the State Department of Education, a uniform accounting of the prior fiscal year's expenditures for each school within the district using the model developed pursuant to subsection (a). The department shall publish this information for all schools in the state by September 1, 1996.

### California School Finance Network.

A. The California Department of Education shall establish a statewide electronic telecommunication network for the purposes of electronically transferring financial data between the county offices of education and the State Department of Education. This network shall be named the California School Finance Network. In establishing the network, the Department of Education shall utilize existing statewide networks.

B. County Offices of Education will transfer mandated fiscal data to the State Department of Education of the California School Finance Network in a format specified by the Department of Education, after consultation with the County Offices of Education.

C. The State Department of Education shall establish a California School Finance Management Information System. This system shall enable California school districts and county Offices of Education to directly

access education data necessary for statewide comparative analysis of school financial practices. California school districts and county Offices of Education shall access the California School Finance Management Information System through the California School Finance Network.

D. The California School Finance Network shall be implemented in a two-phase process. Phase I will initiate data transfer, bulletin board, electronic mail, data validation, software development, and management information system development. These systems will be tested and evaluated in pilot counties to be identified by the Department of Education. Phase I will start July 1, 1992 and be completed by April 1993. Phase II will expand these functions to the remaining county Offices of Education statewide. County Office of Education access to the California School Finance Management Information System will also be implemented. Phase II shall be complete by July 1, 1994.

E. The California School Finance Network shall be implemented according to current state rules and regulations with the review and approval of the state Department of Finance — Office of Information Technology. An interim implementation report shall be submitted by April 1, 1993. The post-implementation evaluation report shall be submitted to the Legislature on or before July 1, 1994.

F. It is the intent of the Legislature to make available funding for the two-year implementation of the California School Finance Network as part of the 1992 and 1993 Budget Acts.

**Intervention.**

The governing board of each school district is responsible for ensuring that each school meets a level of performance that adequately prepares students for adult life. It is the intent of the legislature that districts assist low-performing schools to improve the quality of instruction provided by such schools.

A. The Superintendent of Public Instruction shall issue standards that all schools must meet in order to provide a minimum level of education to students.

B. Governing boards must annually review the performance of schools within each district and identify schools that do not meet the minimum performance standards set by the SPI. When a board identifies a school that does not meet the standards, the board shall:

1. Require the school site council or school management team to develop a plan to improve the performance of students at the school. The plan must specifically address identified areas of low performance and the performance of different ethnic groups.
2. Provide district resources needed to assist the school to improve its educational performance.
3. Consult with the state department regarding models and strategies or other assistance that could assist the school to improve its educational program.

C. If the governing board determines that a low-performing school has been unable to make significant improvements in its program two years after identification by the board pursuant to subsection (b), the board shall:

1. Request the SPI provide a list of names from which the board shall appoint an external support team to assist the school in improving its educational program.
2. Request funds from the SPI to implement a plan of improvement agreed to by the external support team and the governing board.

D. If the governing board and the external support team are unable to agree on a plan of improvement for submittal to the SPI, the board and the support team shall separately submit to the SPI its recommended plan. The SPI shall review the plans and shall recommend to the governing board an improvement plan, based on the two plans submitted. The governing board must implement the plan recommended by the SPI. The board may appeal the SPI's recommendation to the State Board of Education if the board believes the plan would jeopardize the financial or educational stability of schools within the district.

**Performance Awards.**

A. The Superintendent of Public Instruction shall annually determine the 35 elementary schools, 35 middle schools, and 35 high schools that demonstrate the highest performance of all similar schools in the state, based on the progress students within the schools have made during the previous school year.

B. It is the intent of the Legislature to make funds available in the 1992 Budget Act and subsequent budget acts to provide $4,000 awards to each school identified by the SPI as high performing schools.

**Assessment of Teachers.**

The SPI shall establish a commission to develop various approaches to performance-based assessment of teachers. The approaches would be intended to replace existing self-assessments and complement continuing education requirements and new teacher assessments. The performance-based standards would set specific standards for teachers, against which individual teacher performance could be compared.

## CHAPTER 4
## SUPPORTING EDUCATIONAL EXCELLENCE

There is an increasing realization that many crucial influences upon the education of students are outside the school's orbit, and schools cannot do it all. Only an alliance of parents, social service agencies, and educators can make a significant difference for children with multiple needs and dysfunctional families.

The current structure of state and local government is a major barrier to coordinating services. The Legislature declares and finds that new policy directions can reverse the current pattern and provide services that emphasize prevention, continuity, comprehensive, equity, and accountability.

### ARTICLE I. ENHANCING TEACHER INDUCTION AND PROFESSIONALISM

In an increasingly technological and politically complex world, students must be provided with curricular options that will prepare them to become life-long learners and thinking, productive citizens. A strong core curriculum will give all students a real choice of going on to college, community college, or directly into the workplace.

**California New Teacher Program.**

There is hereby established the California New Teacher Program, to be jointly administered by the Commission on Teacher Credentialing and the California Department of Education, under which individual districts, consortia, and county offices of education would be provided state funding in accordance with an approved multi-year local plan that includes a partial local-funding-match and local in-kind support requirements for the following purposes:

1. Provide up to 50% release time for a support teacher to be paired with each new teacher; the support teacher should be currently assigned or have recent experience at the same grade level or subject area and be in the same school as the new teacher.
2. Provide specialized training for support teachers in communication skills and coaching strategies.
3. Provide specialized training for principals of schools where new teachers are to be assigned. The training shall include:
   a. the appropriate assignment for new teachers,
   b. techniques of evaluating new teachers that concentrate on building self-confidence and a sense of professionalism,
   c. structures for evaluation that reinforce good teaching strategies in a logical, structured way, and
   d. linking of new teachers with resources available at the school, in the district or region, and from nearby teacher training institutions.
4. Utilize proven strategies to enhance the quality of new teachers, including observations in classrooms of experienced teachers, structured simulation, videotaped teaching episodes, interactive video, and performance-based evaluation.
5. Build a feedback with the teacher training institutions from which the new teachers have come, ensuring that the institutions continue to support the new teachers and modify their programs and supportive services based on the needs and performance of the new teachers.
6. Build new teacher networks on a district or regional basis in which the new teachers have the opportunity to share experiences and ideas.
7. Provide for continuing research and pilot projects to evaluate effective strategies to support and assess new teachers.
8. Provide for longitudinal research on the effectiveness of new teacher support and assessment efforts including, but not limited to:
   a. recruitment, induction and retention of ethnic minority teachers,
   b. keeping teachers in the profession for longer than average periods,
   c. maintaining teachers' enthusiasm for the profession,
   d. enhancing their quality of teaching service over time, and
   e. increasing their ability to teach students with diverse cultural backgrounds and needs.
9. Funding for this section shall be appropriated through the 1992-93 Budget Act.

**Mentor Teacher Program.**

A. It is the intent of the Legislature to expand the California Teacher Mentor Program to allow each district currently identifying 5 percent of its certificated classroom teachers as mentors to apply for funding to expand that percentage to a maximum of 10 percent, though increasing no faster then 1 percentage point per year for five years.

B. The application process will be in accordance with standards established by the State Superintendent of Public Instruction, in consultation with a broadly based group of concerned parties, including but not limited to school board members, administrators, teachers, parents, business leaders, and students.

At a minimum, each applicant district shall report on the current utilization of mentors and state the specific benefits which would result from the planned expansion.

**Sustained Mentor Teacher Program.**

There is hereby established the California Sustained Mentor Teacher Program. This program shall combine a state level screening process with a local designation plan. The program shall:

1. Allow existing and past mentor teachers to apply for designation as a sustained mentor teacher. The State Superintendent of Public Instruction, in consultation with a broad based group of concerned parties, shall establish standards, criteria, and, if appropriate, specific tests or other assessments to identify superior knowledge and ability in the areas of curriculum and instructional leadership; the standards may include provisions for periodic re-evaluation.
2. Allow those designated as sustained mentor teachers to be exempt from the three-year time set forth in the California Teacher Mentor Program and would be eligible for an additional $1,000 annual stipend if authorized by the employing school district.
3. Allow districts to apply for sustained mentor teacher program funding grants with the consent of local selection committee. The grant application should detail the plan for deployment of the sustained mentor teachers and specify the additional costs associated with the plan in accordance with a schedule of approved costs adopted by the Superintendent.
4. Allow for the schedule of approved costs to include the $1,000 additional stipend for which the sustained mentors are eligible. Any plan for deployment may include a provision for the sustained mentor teacher to spend, on the average, less than 60 percent of his or her time in the direct instruction of pupils. If approved by the Superintendent, a plan containing such a provision would be deemed to waive that requirement of law.
5. Funding for this section shall be appropriated through the 1992-93 Budget Act.

**Instructional Materials.**

A. While instructional materials evaluation and adoption at the state level have been a meaningful and important element in the reform effort, new technologies necessitate a new approach.

B. It is the intent of the Legislature that the State's instructional materials adoption process shall be modified to shift the evaluation of instructional materials from the State to the Subject Matter Professional Development Projects. The Subject Matter Professional Development Projects shall issue consumer reports on basic instructional materials, including technology-based materials, prepared by teachers participating in the projects. The reports shall:

1. Rate materials with a letter grade as to the consistency with the criteria and standards of quality prescribed in the State Board of Education's adopted curriculum frameworks;
2. Reinforce a direct and powerful tie with instructional materials to staff development and to program and student assessment.

C. Beginning in 1992-93 the State Superintendent of Public Instruction shall ensure that the consumer reports are disseminated to schools and shall provide technical assistance to both the Subject Matter Professional Development Projects and the schools.

The State Department of Education's budget which funds the instructional materials process will be redirected to support this effort. Funding to support the periodic reviews conducted by the Subject Matter Professional Development Projects shall be made through the annual Budget Act.

## Article II Curriculum Improvement for All Students.

### California Center for Educational Technology.

A. There is hereby established a California Center for Educational Technology which shall be a joint venture between the State Department of Education, institutions of higher education, local educational agencies, and the private sector. The center shall assist schools in the application of new technology capable of stimulating change in the basic approach to classroom teaching. The center shall develop strategies which will emphasize the following educational services:

1. Curriculum enhancement to meet the needs of high-risk pupils.
2. Expanded course offerings, in subjects that include, but are not limited to, science and mathematics.
3. Expanded course offerings to remote parts of the state.
4. Staff development courses for elementary and secondary school teachers.
5. Curriculum enhancement through increased communication capability of schools, college and universities providing the opportunities for institutions to receive varied types of supplementary educational programs.

B. Funding for this section shall be appropriated through the 1992 Budget Act.

### Software Development.

A. Local educational agencies, in partnership with publishers and the California Department of Education, shall develop software and multimedia programs which include, but are not limited to, complete courses or units of study in all subject area, with an emphasis on science, mathematics, English-language arts, and history-social science. These instructional resources, to be made available commercially, shall be suitable for use by all students, including those who are at risk of not reaching their potential.

B. Initial support for the development of marketing of these products shall come from existing Educational Technology Program funds. Eventually, developmental cost shall be covered by royalties from out-of-state sales of the products developed under the program.

# Improving Student Performance Through Learning Technologies

**Policy Statement of the Council of**
**Chief State School Officers**
**1991**

## POTENTIAL

Learning technologies have an enormous capacity to support and advance restructuring of teaching and learning. Our nation must use technology's potential to improve elementary and secondary education and to provide all learners with the knowledge, skills, and experience they need to be responsible and caring family members, productive workers, and informed global citizens.

"Learning technologies" encompass a wide range of equipment and applications that directly or indirectly affect student performance. Learning technologies range from ordinary telephones, which connect parents with teachers, to complex networks of satellites, cable, and fiber optics, which deliver interactive, multimedia learning opportunities. Technologies are tools. Their power as learning instruments is not inherent; their effectiveness is derived from the teachers and students who use them. This effectiveness is measured by whether they improve student performance and help students reach full potential.

Technologies offer information in a variety of formats—text, video, and audio—allowing students to use the medium most effective for their learning. General or standard transmission of information through the technologies enables teachers to focus their energies on coaching students with their individual growth. Teachers can give special attention to certain individuals without neglecting the progress of others who are successfully guiding their own learning. Technologies enable students working individually or in small groups to take advantage of vast sources of information and work with complex connections among varied disciplines. Technologies stimulate students as active learners who control the pace and direction of content, questions, and responses.

Learning technologies can provide students and teachers equitable access to learning no matter the geographic location or fixed resources of the school. Telecommunications provide students and teachers with the information resources of distant libraries, museums, and universities. Telecommunications offer courses, degree programs, and career development. Learning technologies expand the opportunities of teachers, students, and parents to connect learning activities in school with those in homes, community centers, and other institutions. They provide access to colleagues and specialists around the world and connect student work to the problems and real work of other students and adults.

Learning technologies are the tools for productive, high-performance workers in the 21st century. In the "Information Age," the workforce must be prepared to manage substantial amounts of information, analyze complicated situations for decision making, and react rapidly in a well- informed manner. Equitable availability of learning technologies is essential to prepare all students to be adults with access to productive employment and community and political power. To keep up with the tools of the future workplace and the technologies of the home, all students must have access to them and master their use.

Technologies are productive tools for teachers and administrators to automate record-keeping, student information, and data for accountability. They help provide convenient and timely access to essential information on student outcomes, thereby helping teachers tailor instructional programs to meet specific student needs.

## STATE ACTION

Most states, districts, and schools have successfully used some technologies to develop effective, exciting, and innovative learning environments. To stimulate systemic change and move beyond isolated model programs toward widespread integration of technology into learning, we must commit our efforts to these activities: planning at the state and local levels; funding; ensuring equitable access to technology; human resource training and support; expanding telecommunications networks; developing technology-based assessment tools; and establishing national leadership for learning technologies. To realize the potential for learning technologies, states must take action, both individually and together, as stated in the following "Recommendations for Implementation."

States are at different stages in the development and use of learning technologies. Some have made bold moves or are ready to make a quantum leap in their actions. Many have completed steps such as those recommended below. Where bold actions have been taken, they are applauded as examples for other states to emulate. The comprehensive order of this paper is in no way intended to slow progress of any state to back-track or adjust its previous actions to the systemic approach suggested here. Quite the contrary, the intention is to encourage the leaders who have accomplished certain steps to maintain their leadership toward complete implementation.

The recommendations that follow provide guidance for a comprehensive approach to incorporating technologies into the center of teaching and learning. These are generic proposals intended for all states but not detailed to apply to any specific state. Each state must develop its own application, informed by this comprehensive design and cognizant that each of the components must be included in some form to ensure a complete and effective state strategy.

## RECOMMENDATIONS FOR IMPLEMENTATION

### 1) Develop a State Plan for the Use of Technology in Education

States should establish a clear, long-term, strategic plan for learning technologies. The plan should provide a vision of technology's role in education services, propose effective uses of funds, ensure equitable access to technology, and maximize connections among technologies.

- **Provide a state vision of technology's role in education.** States must communicate a clear and persuasive vision of technology's role in education to ensure that all key persons — the governor, legislators, state education agency staff, higher education authorities, school board members, administrators, teachers, parents, and students — work toward a common goal for technology use.
- **Include certain key components in state and local plans.** State and local plans for implementing the use of learning technologies should include an identification of needs; clearly defined goals and objectives; an evaluation of each selected technology's capabilities and cost-effectiveness; a description of the governance structure and systems operation; a delineation of current and future funding sources; a strategy for teacher, administrative, and support staff training; strategy and schedule for implementing the plan; procedures for assisting local education agencies in the development of local technology plans; an evaluation plan; and a mechanism for modifying the plan itself. Planning is an ongoing process. Plans should be continually re-evaluated based on program outcomes, analysis of program effectiveness, new research, and technology development.
- **Outline the responsibilities at the state, district, and building levels to ensure that the technology plan is successfully developed and implemented.** Each state should determine the planning process that best fits its needs; there is no single planning process for all states. With a trend towards site-based decision making, districts and schools are increasingly responsible for planning and implementing technology programs to

meet their specific needs. At the same time, the economies of scale derived from aggregate purchases and the use of telecommunications networks for large-scale delivery drive planning to higher levels within and among states.

While specific responsibilities vary by state, educators from different levels of each state's education system should participate in planning to achieve full integration of technology into education and to ensure clarity of responsibility and action at each level. Technology plans at each level should be developed by teams that include financial and policy decision makers, teacher and administrator representatives; post-secondary and higher education representatives; technical experts; individuals with experience in curriculum development, instructional management, and assessment; and other major stakeholders in education.

- **Ensure that plans for other programs within state education agencies incorporate the use of appropriate technology.** State education agency plans for the state and federal programs should incorporate the use of appropriate technology to ensure that technology is effectively integrated into each state education service and across the services.
- **Share the state vision and plan with other state agencies.**

2) **Ensure that the State, Districts, and Schools Have Sufficient Funding to Initiate and Sustain On-Going Use of Technology as Articulated in the State Plan**

- **Develop a bold new plan to provide steady funding for learning technologies.** Technology is an integral part of education; consequently, the federal, state, and local governments are responsible for providing funds to initiate and sustain the use of educational technology. Funding should cover all costs associated with the technology and the necessary support for continuing effective use, such as training, maintenance, and upgrades. Avenues to decrease the cost of technology by aggregating purchases across the nation, state, or regions should be developed to the full extent. To supplement federal, state, and local funds, alternative funding options, such as business-state partnerships and foundation grants, should also be pursued.
- **Initiate state development of learning technologies.** States are in a unique position to stimulate and initiate the development of learning technology products. States should use this opportunity to undertake cost-effective projects in technology, which support the state's curriculum frameworks and education goals.
- **Include expenditures for technology as part of capital outlay.** Investments in educational technology should be considered capital expenditures, which may be depreciated over the life of the product.

3) **Ensure that Students and School Personnel Have Equitable Access to Technologies for Their Learning, Teaching, and Management Needs**

Equitable access must be addressed at the national, state, district, and building levels. Access to current technologies and fully interactive information networks that transfer voice, video, and data must be provided.

- **Federal and state policies should ensure access to learning technologies.** Many current federal and state policies were developed prior to the introduction of new technology into education. Such policies may now limit access to technology and, therefore, it is imperative to review them for currency and equitable access. The following issues are especially important for policy review and update:

  **Cost of access:** To ensure that students and school personnel have affordable access to technology and information networks, it is necessary for technology providers to establish rates and other policies specifically for educational purposes. What is affordable for education may not be what is affordable for profit-making corporations. For example, state public utility commissions and the Federal Communications Commission should establish special telephone rates for education. The rates must be low enough to enable students and school personnel to take advantage of the voice, video, and data services transmitted over the telecommunications systems. And the rates must also be sufficient to ensure continued investment in development of future applications for the education market. In addition, telecommunications costs should be equitable regardless of the factor of geographic location.

  **Information access:** Intellectual property and copyright laws must be revised to increase student and school personnel access to information and provide them the flexibility to use the information for instructional

purposes. These laws must also ensure that the owners and originators receive adequate recognition and financial reward. In addition, these laws and other policies should encourage development of electronically accessible information sources.

**School facilities design:** School facility design requirements, whether for new schools or for building rehabilitation, must support the use of learning technologies. Electrical outlets and voice, video, and data lines are critical components of the modern school.School facilities must also support new instructional strategies that use technology (including individual or small-group learning, and varied workstations).

- **Use of federal and state funds:** Federal and state policies should authorize purchase of learning technologies with funds currently earmarked for textbooks, instructional materials, and learning resources.
- **Provide access to learning technologies both in and outside the school building just as access to textbooks is provided both in and outside school.** To compensate for unequal technology resources in the home and among schools, extra effort must be made by states, districts, and schools to provide all students access to learning technologies both in and outside school buildings. Schools should establish programs to loan equipment to students and school personnel for home use. Schools, libraries, and other information sources should make their resources accessible during extended or non-school hours.

4) **Ensure that Educators Have the Staff Support, Training, Time, Authority, Incentive, and Resources Necessary to Use Technology Effectively**

- **Encourage local districts and schools to develop "technology teams."** To effectively integrate technology into the classroom, teachers need to work closely with strong support teams that include principals, library media specialists, technicians, and other support staff. Technology teams should include individuals with decision-making authority and expertise in technology, curriculum design, instructional design, and student assessment. Technology teams should provide teachers with technical support to keep equipment operating; inform them about emerging technologies and programs; suggest ways to renew the curriculum through technology; and assist in assessing the outcomes of the learning technologies.
- **Provide professional development activities to facilitate full integration of technology into education.** States must provide rigorous, continuous training to ensure that all educators develop the skills necessary to use technology in their work. Ongoing professional development activities should be offered cooperatively by states, local districts, and vendors to provide training along with technology purchases and upgrades.

  As learning technologies become more powerful and complex, teachers must increase their capacities to use technology. Teachers must learn how to operate available equipment and applications; evaluate the potential of instructional applications; integrate the technology into the curriculum; use technology for administrative and assessment purposes; and develop a willingness to experiment with technology. They must receive training to develop the group management, decision-making, and coaching skills necessary to help students use technology effectively.

  State and local education agency staff must be provided training that helps them understand technology's potential as an instructional, administrative, and assessment tool. They must also be encouraged to experiment with technology-based programs.

  State education agency staff must join with higher education authorities to ensure that licensure requirements encourage professionals to use technology effectively in the learning environment.
- **Provide the time, authority, incentives, and resources necessary to use learning technologies.** The integration of learning technologies at the center of teaching and learning requires substantial changes from the practice of the traditional classroom. Many of the changes pertain to the role of teachers — their use of time, incentives, relationships between colleagues, and the resources available to them. Examples of necessary changes follow:

  Educators must have convenient access to a wide range of technologies in their schools, classrooms, and homes. These include the technologies of the contemporary workplace of other professionals as well as specialized learning technologies. The more opportunity educators have to become comfortable with and competent with technology, the more likely they are to use it in teaching.

  Many elements of the school day must be reviewed. Use of learning technologies may require substantially

different class schedules, class lengths, and class sizes. Such changes cannot be made in isolation but must be part of decisions that authorize different arrangements for cooperation and logistics.

Evaluation criteria and processes for teachers must ensure that they are fairly judged in the effective use of technology and are encouraged to use it. Current criteria and processes may effectively penalize teachers who use technology. For example, if the criteria is to require a teacher to deliver instruction, the teacher who coaches the students to use technology for "delivery" may be penalized.

5) **Encourage the Development and Expansion of Telecommunications Networks**

State, inter-state, national, and international telecommunications networks are critical for providing students and educators equitable access to resources outside the school and establishing connections between the school and the home, the community, and other outside resources.

- **Plan, fund, and build telecommunications networks.** Governors and state legislators, the President and Congress are encouraged to provide support for the coordination and expansion of current telecommunications networks and to develop new statewide, inter-state, national, and international telecommunications networks to serve education.
- **Advocate national standards to increase connections among and use of voice, data, and wide-band video networks.** Telecomputing networks should operate as national, non-proprietary standard telephone networks do. A telephone user can communicate with another user regardless of which telephone companies provide the service. A routing system is needed to communicate across telecomputing networks. National standards and policies for telecommunications are needed to ensure that the networks serve education.
- **To expand distance learning and ensure that it meets acceptable standards, multi-state cooperative agreements are necessary for teacher qualifications and course specifications.** Varying state requirements for certification and course approval currently require teachers of distance learning to meet multiple state certification and course approval requirements. In some cases, teachers are required to take physical exams and demonstrate knowledge of the state's history and government, even though they are not teaching those subjects. Multi-state cooperative agreements are needed to promote high standards for teachers in a manner that facilitates the expansion of distance learning.

  Multi-state agreements on standards for courses offered by distance learning are also needed to ensure effective expansion of learning opportunities.

6) **Support the Use of Technology in Student Assessment to Measure and Report Accumulated Complex Accomplishments and New Student Outcomes**

Learning technologies are valuable tools for strengthening the teaching and learning of critical thinking and problem-solving skills and for measuring these capacities. Technology-based assessments help educators monitor student performance by allowing for: clear statement of multiple student outcomes; measurement of complex indicators of student learning; collection of data; management of information in such forms as portfolios; and the analysis, processing, and timely reporting of testing.

The effective development of technology for student assessment should be encouraged through collaboration among the states, along with key stakeholders at national and local levels.

7) **Develop National Leadership for Learning Technologies**

- **The federal government should establish leadership in learning technologies.** The federal government should institute processes to develop a coordinated vision for the effective use of technology in education. This vision should be based on the Office of Technology Assessment's reports, *Power On!* and *Linking for Learning*. Federal leadership is essential to the nation's efforts in research and development; to provide direction in the development of the national telecommunications infrastructure; and to ensure that all federal education programs incorporate the use of technologies as summarized below.

- **The federal government should provide increased investment in research and development of learning technologies.** To realize the full potential of learning technologies, systematic research must be conducted on how students learn, the capabilities of current and emerging technologies, and the effect of technologies on student outcomes and the learning environment.

  A national research agenda related to technology in education must be developed collaboratively by federal, state, and local education agencies with the federal government playing the primary role in providing increased and consistent funding for research and development of learning technologies and instructional strategies.

- **The federal government should take leadership in the rapid establishment of an infrastructure to support learning technologies.** The use of learning technologies across the nation requires the federal government's leadership in establishing an infrastructure that includes fiber optic cable and other carriers to transmit all signals throughout the nation. This infrastructure must have the capacity to handle all signals including telephone calls, data transmission, fax, graphics, animation, compressed television, full-motion television, and high-definition television.

- **The federal government should ensure the transfer of technologies from federal agencies to state and local education agencies.** The Department of Education should lead an effort to identify and disseminate learning technologies developed and used by the Departments of Defense, Energy, and Commerce, and other federal agencies. The federal investment in learning technologies in such agencies is far more extensive than in the Department of Education. State and local educational systems need access to these technologies through a coordinated dissemination program.

- **CCSSO and other national education organizations should increase advocacy for education's technology needs at the national level.** Federal policies and actions on learning technologies are critical to the availability of such technology at the state and local levels. CCSSO and other national education organizations must increase their efforts of advocacy to ensure that federal telecommunications and technology decisions support improvement of teaching and learning. Strong appeals need to be made to the President, Congress, the federal courts, the Federal Communications Commission, and the Departments of Education, Commerce, and Agriculture. Specifically, CCSSO should continue to take positions on learning technologies authorizations, appropriations, and legislation that effect the national information infrastructure and education's access as it has on the recent legislation and court rulings concerning the Bell Operating Companies' right to manufacture telecommunications equipment and provide information services. As Congress debates future actions concerning such issues as cable interconnectivity, spectrum allocation debates, and intellectual property rights, CCSSO should represent educational concerns.

## CONCLUSION

The potential for technological advances in support of teaching and learning seems limitless. Each new generation of computers, each advance in multimedia applications, and each gain in telecommunications delivery opens more opportunities. Information Age realities seem close to the reach of some students, but the gap between current opportunity and actual use of technology in most schools is enormous.

We hope this paper captures a vision of the opportunities that learning technologies might provide for all. This vision will keep changing as invention follows new paths of technological creation. The vision will help us only if the states and our nation take the steps recommended here to bring the next generation's tools to the hands and minds of our students. The Council of Chief State School Officers is committed to bringing the vision and recommendations here to reality for all American students.